THE

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THE ORGAN OF THE ROYAL AËRONAUTICAL SOCIETY.

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Edited for the Council by J. LAURENCE PRITCHARD, Associate Fellow.

All communications should be addressed to the Editor.

No. 113. MAY, 1920. VOL. XXIV.

Notices of the Royal Aëronautical Society.

Election of Members.

The following members were elected in the various grades as shown at a Council Meeting held on April 20th :—

Associate Fellows.—C. E. R. Osman, Captain P. W. Smith, Major P. Litherland Teed, Lieutenant-Colonel L. F. R. Fell, Major B. C. Carter, A. P. Cole, Captain D. Nicholson, Captain Douglas E. Riddell.

Members.—Captain H. E. P. D. Acland, R. J. Fullwood, Lieutenant-Commander M. Hori, J. H. Maclean, S. Kirtekar.

Associate Members.—R. M. Papilian, W. J. Wilson, S. E. Taylor, Flight Lieutenant R. S. Capon.

Empire Timber Exhibition, 1920.

At the request of the Department of Overseas Trade, it is desired to call the attention of members to the forthcoming exhibition of timbers grown within the British Empire to be held at the Holland Park Skating Rink, London, from July 5th to July 17th, 1920. The classification of the exhibits embraces (*a*) specimens of timber, (*b*) exhibits demonstrating the various uses to which timbers are put, (*c*) wood pulp; the main object of the exhibition being to bring prominently before persons interested the full range of Imperial grown timbers and especially those timbers which up to the present are only very slightly, if at all, known in this country.

The Exhibition Committee includes representatives of the Colonial Office, Crown Agents for the Colonies, Government of India, Self-Governing Dominions, Forestry Commission, and British Societies interested in the production and utilisation of timber.

Council.

As a result of the election held in March, the Council for the year is now constituted as follows :—

Air Commodore R. K. Bagnall Wild, C.M.G., C.B.E., F.Ae.S. (Chairman).
Major-General Sir R. M. Ruck, K.B.E., C.B., C.M.G. (Vice-Chairman).
A. E. Berriman, F.Ae.S.
F. H. Bramwell, F.Ae.S.

Air Commodore H. R. M. Brooke-Popham, C.B., C.M.G., D.S.O., A.F.C., A.F.Ae.S.
Lieutenant-Colonel A. H. Burgoyne, M.P.
Wing Commander T. R. Cave-Browne-Cave, C.B.E., F.Ae.S.
Sir Mackenzie D. Chalmers, K.C.B., C.S.I.
Sir Robert Hadfield, F.R.S., Bt., F.Ae.S.
Professor B. Melvill Jones, A.F.Ae.S.
Major A. R. Low, F.Ae.S.
A. Ogilvie, C.B.E., F.Ae.S.
Lieutenant-Colonel M. O'Gorman, C.B., F.Ae.S.
F. Handley Page, C.B.E., F.Ae.S.
A. J. Sutton Pippard, M.B.E., D.Sc., F.Ae.S.
A. V. Roe.
Lieutenant-Colonel H. T. Tizard, A.F.C., F.Ae.S.
G. Holt Thomas.
Brigadier-General J. G. Weir, C.M.G., C.B.E., F.Ae.S.
Squadron Leader H. E. Wimperis, O.B.E., F.Ae.S.

Honours.

Members will join with the Council in congratulating Major-General Sir R. M. Ruck, Vice-Chairman, on being appointed a Knight Commander of the Order of the British Empire for his valuable work in furthering the interests of the science of aeronautics. Congratulations are also offered to Mr. A. J. Sutton Pippard, Fellow, and Mr. H. C. Watts, Fellow, on becoming Doctors of Science.

Air League.

Major-General Sir R. M. Ruck and Lieutenant-Colonel A. H. Burgoyne, M.P., have been appointed to represent the Society on the Committee of the Air League.

Donations.

The Council desire gratefully to acknowledge the gift of a copy of "The Chemistry and Manufacture of Hydrogen," from the author, Squadron Leader P. Litherland Teed, Associate Fellow, and a set of lantern slides from the Aircraft Manufacturing Company, Limited.

Subscriptions.

It will be seen from the report of the annual general meeting, printed elsewhere in this issue, that it has been found necessary to raise the subscriptions to members immediately unless another large deficit is to be incurred on the current year's working. The Council, in this connection, desire to call the attention of members to the balance sheet for the year 1919 and invite donations and supplementary subscriptions, where members can afford them, as they feel that the increment resulting from the increased subscriptions may, in spite of every effort to economise, prove insufficient to cover expenses during the year 1919.

Scottish Branch.

A series of 10 lectures under the auspices of the Society are to be given at the Universities of Glasgow, Edinburgh, and Dundee, starting on the 3rd of May.

These lectures are in connection with the engineering classes of the university, and it is hoped that this will be the beginning of regular courses being given at the universities in question, in connection with the engineering degree. It is hoped that next year aeronautics will be included in the engineering curriculum.

The course comprises lectures on the following subjects:—Engines, Naviga-

tion and Meteorology, Technique of Flight, and Aircraft Construction, and the lecturers who have been good enough to offer their services are Colonel Bristow, Squadron Leader Wimperis, and Colonel the Master of Sempill.

The branches at Edinburgh and Dundee were opened, and in each case the Lord Provost was in the chair. There was a very large attendance at both openings, and the necessary committees were formed to carry on the work in each district. In each case a lecture was given by Captain Mansell, in the regretted absence of Air Commodore Bagnall Wild, which was very much appreciated.

The lectures for the coming month include one by Mr. Cope on "The Aerial Exploration of the South Pole," and a juvenile lecture to all Glasgow public schoolboys by Squadron Leader Wimperis.

Journal.

In view of the approaching termination of the present session of lectures members are urged to forward original papers on any aspect of the science of aeronautics with which they are qualified to deal, in order that the summer issues of the Journal may not fall off in interest and value.

Forthcoming Arrangements.

May 3rd, 4th, 5th.—Colonel Bristow lectures on "Aircraft Engines" at Glasgow University.

May 10th, 11th.—Squadron Leader Wimperis lectures on "Navigation and Meteorology" at Glasgow University.

May 12th.—Lecture by Major Linton Hope, Fellow, on "Flying-boat Design and Construction."

May 18th, 4 p.m.—Lectures and Publication Committee meeting.
5 p.m.—Council Meeting.

May 26th, 8 p.m.—Lecture by Sir R. T. Glazebrook, K.C.B., F.R.S., on "Some Points of Importance in the Work of the Advisory Committee for Aeronautics."

June 22nd.—Wilbur Wright Memorial Lecture by Commander Hunsaker, U.S.N. (C.C.), on "Naval Architecture in Aeronautics," H.R.H. Prince Albert in the chair.

Antarctic Expedition.

The following Committee has been appointed to consider the aerial plans of the British Antarctic Expedition:—Air Commodore Bagnall Wild (Chairman *ex-officio*), Squadron Leader Carter, Squadron Leader J. E. M. Pritchard, Colonel H. T. Tizard, Squadron Leader H. E. Wimperis.

War Science Committee.

A reply strongly supporting the proposed action has been sent to a letter from the Conjoint Board of Scientific Societies, calling attention to the necessity for closer co-operation between the Services, and institutions and invididuals engaged in scientific research. It is proposed to draw up a memorandum dealing with the matter for submission to the authorities and suggesting a scheme for the mobilisation of a scientific staff without delay and in the most efficient manner.

Civil Engineers (Registration) Bill.

The Council are taking steps to safeguard the interests of technical members in connection with the Bill, making registration of civil engineers compulsory, which the Institution of Civil Engineers propose to present to Parliament.

W. LOCKWOOD MARSH, *Secretary.*

ANNUAL GENERAL MEETING.

The 55th Annual General Meeting of the Society was held in the Society's offices, 7, Albemarle Street, London, at 5 p.m. on Friday, March 30th, 1920. The Chairman, Air Commodore R. K. Bagnall Wild, C.B.E., C.M.G., presided, and the following were present :—

Council: Major-General R. M. Ruck (Vice-Chairman), Sir Mackenzie Chalmers, Wing Commander T. R. Cave-Browne-Cave, Major A. R. Low, and Mr. Ogilvie.

Members: L. A. Martin, J. L. Pritchard, A. J. Sutton Pippard, Miss L. Chitty, C. Holmes Waghorn, Major D. H. Kennedy, Dr. L. E. Stamm, F. P. Walsh, H. E. Mettam, R. H. Mayo, the Master of Sempill, Sir Charles Bright, and H. C. Watts.

The Secretary read the notice convening the meeting.

Miss L. Chitty and Major D. H. Kennedy were appointed scrutineers of the ballot for the election of Council.

The CHAIRMAN in presenting the Council's report and balance sheet referred to the establishment of a strong branch in Scotland under the Chairmanship of Sir William Beardmore, and to the various activities of the Society including the nomination of a representative on the Aeronautical Research Committee.

The report and balance sheet were then adopted *nem. con.*

The Chairman introduced the Council's proposal to amend Rule 5 by adding the words "The Honorary Treasurer shall, if not already an elected member of Council, be an *ex-officio* member of Council, additional to the twenty members hereinbefore referred to, but shall not as such be entitled to vote on matters other than those affecting finance."

Mr. A. E. Turner has kindly consented to act as Honorary Treasurer, and the Council felt that the Honorary Treasurer should have a seat on the Council in order that his opinion might be taken on questions of finance. The amendment was carried unanimously.

The Chairman put the Council's proposals for deleting Rule 26, which lays down the subscription rates for the various grades, and substitute :—

GRADE.	ENTRANCE FEE.	SUBSCRIPTIONS.	
		Elected to the Society in any grade prior to June 1st, 1920.	Elected subsequent to June 1st, 1920.
Fellow	£5 5 0	£5 5 0	£6 6 0
Associate Fellow ...	3 3 0	3 10 0	4 4 0
Student	—	1 1 0	1 1 0
Member	1 1 0	3 3 0	4 4 0
Associate Member ...	—	1 10 0	2 2 0
Founder Member ...	—	1 10 0	2 2 0
Foreign Member ...	—	1 10 0	2 2 0

He said that from a variety of causes, detailed in the Council's report, the financial position had become difficult and it was felt that, in common with other

similar bodies, a revision of the subscription rates had become necessary. His only doubt was as to whether the proposed increases were sufficient. He himself would like to see the subscriptions doubled, which would result in an increased revenue of £1,700. The Council's proposal should bring in an increase from present members of about £1,000 in the current year; of the adequacy of which he personally had some doubts. He felt, however, that he might be unduly pessimistic, and therefore called upon General Ruck, who he thought was more optimistic, to express his views to the meeting.

General Ruck said that he quite agreed that if the Society's activities were to be extended, double subscriptions would be necessary, but he felt that we should draw in our horns for a little, as the Society grew with the industry and must share in the slump. He recalled how the financial position had improved during the last eight years, and how disappointing last year proved owing to the falling off of advertisements in the Journal. He did not see how expenditure could have been reduced very much. He felt, and believed that members would agree, that the £650 donation to Mr. Faraday was thoroughly justified, as he had come in at a very low salary on the understanding that when things looked brighter this would be increased. The garden party in the summer was another expense that might have been saved, but he thought that this had done the Society good. He hoped that it would not be necessary to double the subscriptions of present members, though he thought that new members should pay double the present rates.

The Council's proposal was then put and carried *nem. con.*

The Chairman introduced the Council's proposal to delete Rule 32 and substitute :—

" Any member of the Society may, on and after January 1st, 1920, compound his subscription for life by paying a sum equivalent to fifteen years purchase of the subscription for which he is liable. This payment shall cover his initial entrance fee if made within fourteen days of election. Any life member desiring to transfer to life membership in a grade involving a higher subscription, to do so on an equivalent basis (*i.e.*, fifteen years' purchase of the difference between the two subscriptions). Any life member transferring to membership involving a higher subscription, but not wishing to compound the new subscription, shall only be called upon to pay annually the difference between the subscription in his old grade and that of the grade transferred to. Should a life member resign or be expelled from the Society, no part of the life composition paid by him shall be returned."

He pointed out that this would provide a properly graded composition fee for life membership in accordance with the practice of other societies.

The proposal was carried *nem. con.*

The CHAIRMAN then put the Council's amendment to Rule 33, substituting the words " January 1st, 1920 " for " November 1st, 1911."

The proposal was carried *nem. con.*

The CHAIRMAN, on behalf of the Council, asked for the authorisation of the meeting to draw up and put into force regulations for the institution of examinations for Associate Fellowship. After some discussion the motion was finally passed in the following form :—" The Council are authorised to draw up, and, subject to confirmation at a general meeting of voters put into force, regulations for the institution of examinations for Associate Fellowship of the Society." Major Low dissented on the ground that a general meeting was only concerned with the principle, the details of rules and regulations being left to the Council.

The composition of committees and representatives on other bodies was then considered, and the following appointed :—

TECHNICAL TERMS COMMITTEE.

Air Com. Bagnall Wild.
Mr. L. Bairstow.
Eng.-Cmdr. W. Briggs.
W. Cannell (S.B.A.C.).
Wing Cmdr. Cave (Airship Dep. Air Min.)
E. G. Chapman (Patent Office).
Capt. P. E. Doherty (Supplies).
Fl. O. M. A. Doyle (D. of R.).
H. Glauert (R.A.E.).
C. G. Grey (R.Ae.C.).
Major D. H. Kennedy.
Lieut.-Col. J. H. Landon (Tech. Dep. Air Min.).
Major Ledeboer (D.A.P.).
Major A. R. Low (R.Ae.S.).
R. Borlase Matthews (Tech. Dep. Air Min.).
A. Winter Moore (Min. of Mun.).
Capt. J. Morris.
Major H. Myers (A.I.D.).
Col. O'Gorman (R.Ae.S., B.E.S.A.), Chairman.
S. W. Phillips (D. of R).
R. K. Pierson (S.B.A.C.).
F. J. Selby (A.C.A.),
Sir Napier Shaw (Met. Office).
Major Wylie (Air Min.).

FINANCE COMMITTEE.

Air Com. Bagnall Wild.
General Ruck.
A. Ogilvie.
A. E. Turner.
Holt Thomas.
H. White Smith.

LECTURES AND PUBLICATIONS COMMITTEE.

Air Com. Bagnall Wild.
L. Bairstow.
F. H. Bramwell.
Wing Comdr. Cave-Browne-Cave.
Major A. R. Low.
Col. O'Gorman.
A. Ogilvie.
J. L. Pritchard (Editor).
M. A. S. Riach.
A. J. Rowledge.
Maj.-Gen. Sir R. M. Ruck.

LIBRARY COMMITTEE.

Air Com. Bagnall Wild.
Sir Mackenzie Chalmers.
Lieut.-Col. T. O'B. Hubbard.
Major A. R. Low.
F. Handley Page.
J. L. Pritchard (Editor).
Sir W. Raleigh.
Dr. R. M. Walmsley.
Mrs. E. MacAlister (Hon. Librarian).

CANDIDATES' QUALIFICATIONS COMMITTEE.

L. Bairstow.
Air Com. Bagnall Wild.
Prof. B. Melvill Jones.
Major A. R. Low.
A. J. Sutton Pippard.
Squadron Leader J. E. M. Pritchard.
M. A. S. Riach.

EXAMINATIONS COMMITTEE.

Wing Cmdr. Cave-Browne-Cave (Chairman).
Major Low.
N. A. V. Piercy.
A. J. Sutton Pippard.
J. L. Pritchard.
Dr. Walmsley.

REPRESENTATIVES ON OTHER BODIES.

Conjoint Board.—General Ruck.

British Science Guild.—Major Low.

Aeronautical Research Committee.—A. Ogilvie.

Advisory Committee on Aeronautical Education.—Dr. Walmsley.

B.E.S.A.—Colonel O'Gorman.

Joint Standing Committee with S.B.A.C.—L. Bairstow, A. Ogilvie, Wing Commander Cave-Browne-Cave, Lieutenant-Colonel O'Gorman, F. Handley Page, Major-General Sir R. M. Ruck, Air Commodore Bagnall Wild.

On the proposition of the Chairman the Council were authorised to prepare a scheme for the admission of ground engineers in a special grade, for confirmation at a general meeting.

The scrutineers then presented the result of the ballot, and the following members were declared elected to serve on the Council for the two years ending March, 1922 :—Air Commodore Bagnall Wild, Air Commodore H. R. M. Brooke-Popham, Major-General Sir R. M. Ruck, F. H. Bramwell, Major A. R. Low, Professor B. Melvill Jones, A. J. Sutton Pippard, A. V. Roe, Brigadier-General J. G. Weir, and Squadron Leader H. E. Wimperis.

A hearty vote of thanks was accorded Major Kennedy and Miss L. Chitty for their work in scrutinising the ballot. The proceedings terminated with a vote of thanks to the Chairman, proposed by General Ruck, and seconded by Mr. Ogilvie.

AERIAL
(The Royal

GENERAL INCOME AND EXPENDITURE ACCOUNT

Expenditure.	£	s.	d.
To Office Rental, Lighting and Insurance	339	17	1
,, Salaries	714	0	8
,, Exhibitions and General Meetings	304	13	9
,, Printing, Stationery, etc.	142	16	5
,, Postages and Messengers	173	9	10
,, Library Expenses	49	14	2
,, Office Expenses	173	0	2
,, Journals, Pamphlets, etc.	906	12	4
,, Committees	53	13	0
,, Audit Fees	10	10	0
,, Income Tax	5	12	6
,, Manchester Branch Expenses	10	0	0
,, Special Donation to Secretary as per Minutes of Council of July 29th, 1919	650	0	0
	£3,533	19	11

BALANCE SHEET

Liabilities.	£	s.	d.	£	s.	d.
Nominal Capital	1,000	0	0			
Divided into 20 Shares of 1s. each and 999 Shares of £1 each.						
Capital issued and called up—						
11 Shares issued and fully paid up				0	11	0
Sundry Creditors				1,572	5	5
Subscriptions paid in advance				31	17	0
Reserves and Apportionments				58	1	0
Reserve Fund—						
Entrance Fees and Life Compositions of present Members as at 31st December, 1918	1,868	2	0			
Receipts during 1919	366	14	0			
	2,234	16	0			
Less Reserve Account—						
Excess of Expenditure over Income 1919, exclusive of Entrance Fees 1,780 12 1						
Deduct Surplus 1918 Balance ... 718 15 6						
	1,061	16	7			
				1,172	19	5
				£2,835	13	10

(Approved) R. K. BAGNALL Wild, Brigadier-General
(Approved) A. R. LOW (13/2/20) } *Directors.*

SCIENCE, LTD.

Aeronautical Society).

FROM DECEMBER 31st, 1918, TO DECEMBER 31st, 1919.

	Income.	£ s. d.	£ s. d.
By Annual Subscriptions		1,685 17 10	
,, Dividends on War Loan		67 10 0	
			1,753 7 10
,, Balance, being excess of Expenditure over Income			1,780 12 1
			£3,533 19 11

31st DECEMBER, 1919.

	Assets.	£ s. d.	£ s. d.
Cash at Bank—Coutts and Co.		15 0 6	
Cash in hand		15 4 7	
			30 5 1
Investments at cost price—			
£750 of 5% War Loan		709 6 4	
£100 of 5% War Bonds		100 0 0	
£500 of 5% War Loan (inscribed Stock, 1929/47)		475 13 6	
			1,284 19 10
Office Furniture, Printed Books, Bindings, Stationery, Old Prints, etc., as per last Balance Sheet... ...			322 11 8
Stock of Journals, etc., at Society and with Society Printers, as estimated by the Secretary			30 0 0
Sundry Debtors, including Subscriptions owing ...			1,154 17 3
Reserves for amounts paid in advance			13 0 0
			£2,835 13 10

I beg to report that all my requirements have been complied with by the Directors and Officers of the Company, and that in my opinion the foregoing Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of the Company's affairs, according to the best of my information and the explanations given to me, and as shown by the books of the Company. Investments have been continued at cost price and the "Office Furniture and Library" is entered at the book figure, but is believed to be of considerably greater value.

JAMES E. WARD, *Chartered Accountant*,
London and Birmingham.

February 12th, 1920.

PROCEEDINGS.

NINTH MEETING, 55th SESSION.

The Ninth Meeting of the Fifty-Fifth Session was held in the Theatre of the Royal Society of Arts, London, on Wednesday, March 3, 1920, Colonel H. T. Tizard, Fellow, presiding. Professor Melvill Jones delivered the following lecture :—

FLYING OVER CLOUDS IN RELATION TO COMMERCIAL AERONAUTICS.

1. Colonel Festing, at a meeting of the Geographical Society some time ago, remarked that these islands are peculiarly badly situated for commercial flying on a large scale, both on account of their position far from the universal junction of air routes, Egypt, and on account of their weather. This appears to me to be a very true saying; one might liken our position in relation to the world of aviation of the future to our position in relation to the ancient Roman Empire; a pokey, misty little place that no one wants to go to, situated somewhere near the ends of the earth.

2. Now it does not take a very vivid imagination to foresee a time, not very far distant, when aerial traffic will have a serious, if not perhaps a predominating, influence on international commerce, and, when that time comes, the nation that is disadvantageously placed aerially will be in much the same position as the unfortunate nations that had bad seaports when sea traffic was becoming an important factor in international trade.

3. I do not wish to be interpreted as thinking that this time is immediately upon us, all I say is that it is bound to come some time, and that it may come sooner than one is apt to think in the present period of temporary aeronautical depression that has inevitably followed the termination of the war.

4. Now we cannot pick up our island bodily and transport it to a more favourable position, nor can we alter our weather, but we can see to it that we push along to the utmost every method of science and organisation that will improve long-distance flying in bad weather, and so at least reduce our natural handicap.

5. This problem of bad weather is peculiarly our own concern. To most other nations it is a matter of minor importance; it is even to their advantage that progress should not occur in this direction, since every improvement in methods of bad weather flying helps to throw off some of our natural aerial handicap. It is thus of particular importance that we should make a special study of bad weather flying, and particularly direct our attention to methods and organisation likely to give the best results in the long run, since it is later on and not immediately that our *aerial* handicap will be felt as a *commercial* handicap.

6. Bad aerial weather is really bad visibility weather, for except for very high winds, that are comparatively rare, it is low visibility, due to clouds, mist and fog, that is our great handicap in these islands. Now at the present time, fog, which I take, for aerial purposes, to mean clouds down to the ground where one wants to land, is beyond us altogether. I do not think it will be so for ever, but undoubtedly we do not at present know of any method of landing safely in fog on anything but an indefinitely large aerodrome. I shall therefore not discuss fog, excepting only the problem of how to know it is there, so as to go away to some temporarily more favoured place. Fog, widely spread over the country, we shall take as an act of God that prevents us flying altogether.

7. The problem I propose to consider to-night is that of long-distance flight when the country is covered with a practically continuous layer of clouds with low under surface and bad weather underneath—the kind of day in fact that we know, to our cost, predominates in this country in the winter months. The more pleasing kind of day that is cloudy, but on which the clouds are sufficiently broken to allow of one flying between or over them without entirely losing touch with the ground, I class as fine and place it out of our consideration to-night.

8. To assist you in getting a grip of what might otherwise be rather a diffuse argument, I shall, at this point, give a condensation of the argument that I propose to try and develop to-night. I do not expect everyone to agree with this argument, I rather hope that some people won't and will give their views with vigour in the discussion to follow. I am definitely taking sides in the argument, the side that over-cloud flying will, if properly conducted, prove ultimately to be the best way of tackling the type of bad weather that I have just described. Time and the speakers to-night may prove this standpoint to be wrong. At the worst I hope to stimulate thought and public discussion on what I feel to be a point of considerable importance. The most condensed form of my argument that I can devise is as follows:—

9. On cloudy days one can fly either beneath or above the clouds; in connection with each method there are difficulties and dangers, but these are of an entirely different type in the two cases. Peculiarities of each method may be summarised as follows:—

1. Under-cloud flying can be successfully performed commercially by individual effort, but will always be at a serious disadvantage compared with fine weather flying.
2. Over-cloud flying can *only* be engaged in *commercially* with the assistance of organisation on a large scale, and with certain apparatus, additional to what is essential for fine weather; given these conditions, however, it is capable of development to such an extent that it is very little inferior to fine weather flying as a commercial proposition.
3. Individual effort, unless assisted by far-seeing organisation on a large scale, is liable, of necessity, to develop under-cloud commercial flying at the expense of the alternative method, although the latter is likely to achieve better results in the long run.

Difficulties of Flying Under Clouds.

10. For the sake of clearness I have classified the objections to under-cloud flying as follows. These are not necessarily given in order of importance.

1. Strain to pilot.
2. Danger of collision.
3. Discomfort to passengers and pilots.
4. Loss of power to use favourable winds.
5. Annoyance to people on ground.
6. Danger in forced landings.

11. I will deal with these drawbacks in detail in order to develop the first part of my argument, *i.e.*, that under-cloud flying on bad days, whilst being possible to determined individual effort, will always suffer from serious drawbacks in spite of any foreseeable developments in organisation or science.

Pilot Strain.

12. I speak with some diffidence here because there must be many pilots in the audience who have more and later experience of under-cloud flying than I have. In my experience the strain of long continued under-cloud flying, when the clouds

are low and the visibility bad, is very great. This is mainly due to the incessant watchfulness that is necessary to avoid losing the way, and to avoid collisions when the air is at all crowded. The strain is, however, accentuated by the almost continuous bumps that are usually encountered. The mere physical effort of counteracting these bumps for hours on end is quite fatiguing, to say nothing of the weariness, due to being shaken about, comparable with that produced by a long motor drive on very bad roads. The contrast between the mental and physical effort required under these conditions and when merely keeping a compass course above clouds in clear air, free from bumps, must be felt to be believed. This contrast will probably be accentuated in time by the use of gyro automatic course maintainers in the latter case.

Danger from Collisions.

13. When the clouds are low, say below 2,000 feet, everyone flies as high as possible without losing sight of the ground, so that almost all aircraft will be confined, on these days, to a layer no more than 200 feet thick. This greatly increases the chances of collision. Immediately under clouds, on bad days, the horizontal visibility is very low, and this still further increases the danger of collision. I believe that this difficulty will become very serious when the air becomes crowded. At present it is not serious except in the neighbourhood of aerodromes. When flying over clouds in clear air, collision dangers are practically non-existent. The problem of avoiding collision *in* clouds will be dealt with later.

Discomfort of Passengers and Pilot.

14. The contrast between the pleasure of flying over clouds and the discomfort of flying under clouds in bad weather is very great, and must be felt to be believed. It is difficult to convey any idea of the feeling of exhilaration produced by the absolute isolation, the clear blue sky above and the brilliant white cloud forms beneath. The only way to appreciate the feeling is to get above the clouds, either on a mountain or in an aeroplane. Flying under clouds on a bad day, on the other hand, is like a channel crossing in rough weather. Seriously, I think that this is a very important commercial consideration from the point of view of passenger-carrying.

15. I cannot imagine anyone undertaking a long flight under clouds in bad weather, except as a matter of duty, or for the sake of experience. Consideration of personal comfort alone might well decide a man to travel by air in fine weather or on a flight over clouds in bad weather, but if a low flight in bad weather is contemplated, the man who likes comfort will undoubtedly stick to the train.

Loss of Choice of Height.

16. The economy of commercial flying will depend largely upon the intelligent use of favouring air currents at particular heights. In fine weather I imagine this will be the determining factor of height. On bad days, pilots who can choose between flying under or over clouds, with perhaps considerable choice of height in the latter case, will have a very great pull over pilots who are forced to keep low; it is quite an ordinary occurrence for the wind at a great height to be exactly the opposite to the wind near the ground.

Annoyance to People on the Ground.

17. This does not at present sound a very serious matter, but I venture to suggest that people living on a heavily used route along which the large multi-engined machines pass close overhead during most of the winter, will get restive, to say the least of it. Whether their restiveness will do them any good, or the aircraft any harm, is another matter.

Danger in Forced Landings.

18. Forced landings in bad weather will be dangerous either from above or below clouds. One hopes they will get fewer and fewer as time goes on; if they don't, bad weather flying of any kind will be impracticable; they will, however, always have to be reckoned with to some extent. The worst case when flying low is when the engine fails whilst flying down wind; a rapid turn then has to be made, with consequent loss of precious height and choice of landing ground. One has, however, the advantage when flying below clouds that one has a fairly clear idea of the lie of the land at the moment the engine fails.

19. In forced landings from over clouds one has not the latter advantage, but one has two balancing advantages:—

1. There is time to consider possible trivial causes of failure and to right them, thus avoiding the forced landing altogether in a large number of cases. There is no time for this from a low height as the attention from the start must be focussed on the actual landing.
2. If the pilot possesses a knowledge of the wind direction near the ground, he should arrive through the clouds already flying up wind and with a mind alert to the danger.

20. The difficulty of the clouds extending to the ground, when one is above clouds, will be discussed later; when below clouds one can see this difficulty coming and avoid it.

21. The arguments just discussed form a rough survey, so far as I myself am able to analyse them, of the reasons why I feel that under-cloud flying on bad days, when the clouds are low, is not going to be a very satisfactory operation, particularly when carried out over crowded land areas, such as the British Isles. Over-sea flying is quite another matter and does not come into the scope of this paper. The actual weight of these arguments cannot be estimated by any theoretical process, it is largely a matter of experience, and I am here giving my personal conclusions, based on a limited experience, together with the best analysis I can make of the reasons that underlie them. I have tried to bring out the advantages of over-cloud flying in direct contrast to each drawback of under-cloud flying; apart from the dangers and difficulties of over-cloud flying that I now propose to discuss, these advantages are such that I imagine that there would be no hesitation in deciding for over-cloud flying in bad weather, whenever possible.

Difficulties of Over-Cloud Flying.

22. We will turn now to a discussion of the difficulties and dangers of over-cloud flying and attempt to develop my second argument, namely, that over-cloud flying can *only* be indulged in *commercially* with the assistance of a large organisation and with special apparatus, but that, given these, it shows possibilities of development to such a pitch that it will be little inferior for commercial purposes to fine weather flying.

23. As in the former case, I will begin by roughly classifying the difficulties and dangers and then deal with each in detail.

My classification is as follows:—

1. Difficulty of actual in-cloud flying.
2. Danger that the clouds may come to the ground whilst aeroplane is in or above them.
3. Difficulty of navigation.
4. Difficulty of aerodrome finding at end of flight.
5. Danger of collision in clouds.
6. Possibility of having to reach great heights to clear clouds.
7. Danger from storm clouds.

Flying in Clouds.

24. The first difficulty, that of flying in clouds, could, for the purposes of this argument, be dismissed in the following words:—" Flying in cloud, although requiring special apparatus and training of a simple kind, presents a problem that has already been completely overcome." At first I thought of dismissing this subject in this way for the sake of brevity and clearness of my argument, but eventually I decided that it would be a favourable opportunity to discuss briefly the underlying reasons that make cloud flying difficult, and the methods by which the difficulties can be overcome. I will therefore ask you to consider this part of my paper as somewhat of a digression from the main course of the argument.

25. The essence of the difficulty of flying in cloud lies in the fact that it is impossible to distinguish between the effects of gravity and of acceleration. For instance, a man in a lift that is accelerating downwards imagines that his weight has become reduced, and but for the fact that his other senses, such as sight and hearing, may tell him he is in a lift and therefore probably descending or ascending, he has no way of telling that his weight has not been reduced by the earth getting tired of pulling at him. In other words, an acceleration, or rate of generation of motion, cannot be distinguished from a change of weight.

26. Now consider a man in an aeroplane that is turning in a curve; most of you know that under these conditions his acceleration, or rate of change of motion, will be at right angles to his momentary direction of motion.

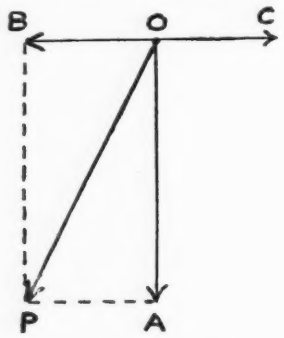


FIG 1.

27. Suppose O (Fig. 1) is an aeroplane travelling into the paper, but turning to the right. Its acceleration is to the right along OC, and the pilot cannot distinguish this fact from what would occur if there were an additional earth out to the left attracting him to the left along OB.

28. The combination of this imaginary earth pulling along OB and the real one pulling along OA, the true vertical, produces the effect of a somewhat stronger earth than the real one pulling in the new direction OP. In other words, the pilot has an apparent new vertical, and has no internal means of knowing that this is not the true vertical except that he will feel a little heavier than usual, by just as much as OP is longer than OA.

29. Now it is easy to see that OP does not grow much bigger than OA until the angle POA is quite large, and a man does not seem, in practice, to be at all sensitive to small changes in weight, especially when the change is gradual. Hence, in practice there is no means of telling that the apparent vertical is not the true one until the angle between the true and the false vertical is very large; even then, only the fact that the vertical is wrong is appreciated, not the direction in which the error lies. Any experienced pilot will realise this point

at once from the fact that he can sit quite squarely in his machine with his cross bubble in the centre on quite a steep bank, provided that the bank is correct for the turn.

30. The fact we have discussed introduces no difficulties to a trained pilot flying in the open, because he preserves his idea of the vertical by looking at the horizon; all pilots do this whether they know it or not. Once let the pilot enter a cloud, however, where he cannot see the horizon, and the fact just considered becomes of vital importance.

31. Let us follow the case of a pilot, unequipped for cloud flying, who enters a cloud for the first time, and let us imagine that he has no compass. He goes in quite straight and level and, if he is a fairly experienced pilot, keeps his speed moderately constant for some time, using his elevator, either by feel or with the help of his speed indicator. The inside of a cloud however is generally very bumpy, and in trying to correct these bumps he gets upon a bank and starts a turn, his instinctive correction then only results in making the bank and the turn suit each other, *not* in levelling him up again, and for some time, greater or less according to chance, he goes on in blissful ignorance that he is steadily getting on to a steeper and steeper bank and a sharper and sharper turn. All this time he would take his oath that he is perfectly level, and if, during this stage, which may last a minute or two (this seems a long time in a cloud), he comes out of the cloud again, he probably rights himself and goes on with the mistaken belief, that may subsequently cost him his life, that he can fly in clouds.

32. Let us suppose, however, that the cloud is a large one; his first indication that something is wrong is, as a rule, either an increase or decrease of speed that is not counteracted by the accustomed movements of the controls. A period of wild suspense and utter bewilderment now follows, during which the pilot makes violent efforts to recover control, but without success. The next thing that he realises, if he realises anything at all, is that he is either on his back or spinning, and the next thing he knows is that he is out of the clouds with the earth standing up at a ridiculous angle and spinning round like a drunken dinner plate. Happy is he that has plenty of air room under these circumstances.

33. What has happened is obvious to anyone but the unfortunate crew of the aeroplane. The bank has increased without the pilot suspecting it until a new system of control is required to maintain steady conditions; the pilot having no knowledge of this instinctively acts as he would were he level, with the result, chaos!

34. I have not overdrawn this gruesome picture, I have been through it myself as an observant passenger, and have talked to many others who have been through it. Many a good pilot has had his last living view of the earth in this wildly gyrating form.

35. I hope that I have indicated to you that flying through continuous clouds without a compass, or special instruments, is very difficult. When the clouds are low so that there is little air room it is suicidal except to a few very exceptional mortals.

Action of the Compass.

36. Now consider the compass. If all compasses pointed to the north, under all circumstances, cloud flying would be easy. Fly on a compass course, and since you are not turning you can have no continuous lateral acceleration, and your apparent vertical cannot get far wrong. Unfortunately *all* compasses are affected by lateral accelerations in such a way that the north point in the Northern Hemisphere swings towards the direction of acceleration, *i.e.*, to the inside of the curve when turning. I shall not go into the proof of this, which depends on the fact that the earth's field is not horizontal but sloping down to the north;

it will suffice to say that, so far, no practicable way has been discovered of overcoming this difficulty, nor is one likely, in my opinion, to be forthcoming.

37. When flying south this peculiarity of the compass is an advantage rather than a disadvantage, but when flying north the reverse is the case. The diagrams, Figs. 2 and 3, should make this point clear. These are produced from actual experimental figures.

38. Flying north it is clear from Fig. 2 that the compass is of very little help as a means of flying straight; in some cases it is a distinct hindrance. The pilot following his compass is confirmed in his belief that he is flying straight when actually he is turning rapidly; in some cases he is actually encouraged to increase his turn. It must also be remembered that the accelerations produced by bumps, which almost always occur in clouds, disturb the compass very much, so that, even when flying south, control may be lost by an injudicious attempt to follow the perturbations produced in this way.

39. Once the violent accelerations attendant on actual loss of control have started, the gyrations of the compass, as seen from the aeroplane, become something terrible, in a word, it appears to go quite mad, spinning and stopping again in a perfectly diabolical manner, so that the poor pilot who meets these phenomena for the first time is only confirmed in his belief that the laws of nature, as he is accustomed to them, are temporarily suspended. Fig. 4, taken from life, shows a mild case of what can occur on a moderately sharp turn.

40. It must not be supposed from the foregoing remarks that it is impossible to fly in clouds with the aid of a compass and the ordinary instruments only, on the contrary, we even managed during the war to train several formations of comparatively inexperienced pilots to fly so well in clouds that they could actually pass through clouds 6,000 feet thick, in formation, and this without the use of special instruments; the operation, however, was recognised to involve a war risk. Under these conditions the long period compass, the action of which is illustrated in Figs. 2 and 4, was found to be an absolute necessity.

41. Possibly I have said enough to indicate that cloud flying without special instruments, although possible with training, involves too great a risk for commercial purposes, besides being in practice confined to flights not lying within 45° of north.

42. For war purposes the importance of cloud flying is obvious, because of the cover provided by the cloud; vigorous efforts were therefore made to devise instruments to make cloud flying easier, with the result that there are now no less than three types of cloud flying instruments in existence, working on entirely different principles; any one of these makes cloud flying comparatively simple.

These three types can be grouped under the following heads:—

The Static Head Turn Indicator.
The Spinning Top.
The Gyro Turn Indicator.

I will deal with these in turn.

Static Head Turn Indicator.

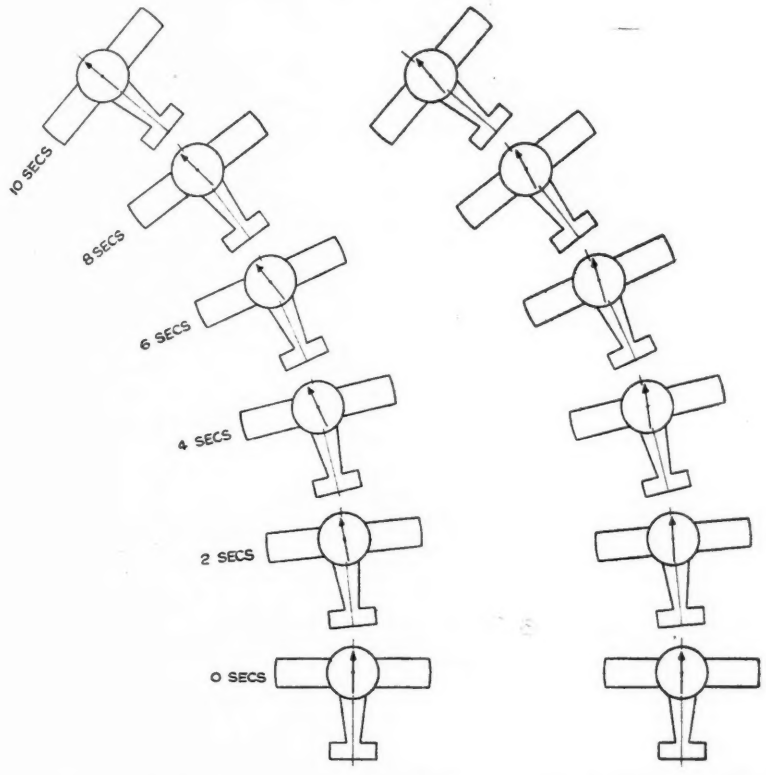
43. The Static Head Turn Indicator, due primarily to Sir Horace Darwin, has already been described in this Society. I will describe it again briefly for the benefit of those who were not then present.

44. A pressure gauge P, Fig. 5, is connected by tubes to two static heads or devices for measuring true pressure S_1S_2; these are situated on the wing tips. The gauge reads a small difference of pressure when the aeroplane is turning owing to the centrifugal force in the tubes T_1 and T_2.

45. So far the device might be thought to be merely equivalent to an

elaborate cross level, whilst the aeroplane is level it reads the same quantity as the ordinary bubble cross level.

46. When the aeroplane banks, however, the tendency of the air to flow down the tubes T_1T_2 is neutralised by the barometric pressure difference between the points S_1S_2, due to their being at different heights. The centrifugal force on the air in the tube is thus still free to make itself felt so that the instrument reads lateral accelerations independently, or nearly independently, of bank. In this, of course, it differs from the bubble cross level.



SHORT PERIOD COMPASS ON SLOW TURN FROM NORTH. 180° TURN IN 40 SECS AT ABOUT 70 M.P.H. CORRESPONDING BANK ABOUT 14°

SPECIAL LONG PERIOD COMPASS UNDER SIMILAR CONDITIONS.

FIG. 2.

47. In any *steady* flight lateral accelerations imply a rate of turn, and hence the instrument, although in reality a thwartships acceleration indicator, may be considered to be a turn indicator.

48. In practice this instrument works very well, and its presence on an aeroplane makes cloud flying safe, since by its use it is always possible to tell which way one is turning or spinning and to apply the necessary corrections on the controls. It has, however, three serious defects for use as the sole extra

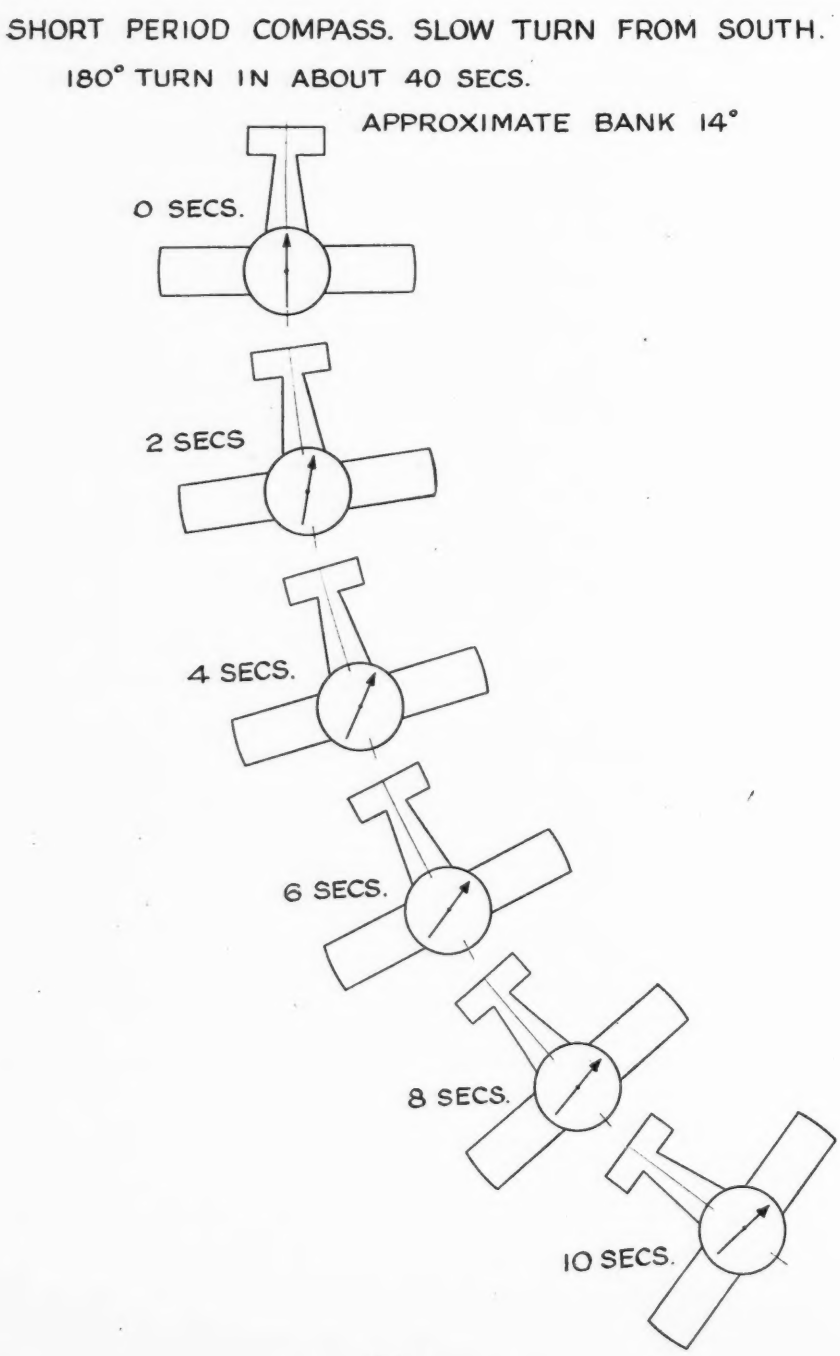

SHORT PERIOD COMPASS. SLOW TURN FROM SOUTH.
180° TURN IN ABOUT 40 SECS.
APPROXIMATE BANK 14°
0 SECS.
2 SECS
4 SECS.
6 SECS.
8 SECS.
10 SECS.

FIG 3

instrument for cloud flying on a commercial machine. These defects are as follows:—

1. The action of the instrument depends on the measurement of very small differences of pressure in the presence of possibilities in the way of violent pressure disturbances due to the rapid air flow past the static heads. It is thus easily put out of order. Kinks in the tube, etc., are sufficient to disturb its reading seriously.
2. As at present constructed there is an excessive "lag" between the starting of the turn and its registration.
3. As at present constructed it is very much influenced by side slip. This is not a fundamental difficulty, but is thought to be due to the unsymmetrical influence of the aeroplane itself on the neighbouring air, when side slipping.
4. It is possible, though rare, for the static heads to freeze up solid and put the instrument out of action. When this happens in a cloud the speed indicator will also be out of action and disaster would probably follow.

49. Defects 1 and 4 relate to reliability, an important matter in commercial work. Defects 2 and 3 make it practically impossible to fly a good straight course, using the turn indicator as the primary instrument; the compass has to be used for this purpose and the turn indicator as an occasional corrector. The defects of a compass as an instrument for flying straight have already been considered. In spite of these defects the Static Head Turn Indicator produced an immense simplification in the art of cloud flying.

Spinning Top.

50. The Spinning Top cloud flying device consists of a top spinning about a point near its centre of gravity and carrying some indication to show the direction in which the axis is pointing. The usual method of doing this is to prolong the axis upwards by a light rod with a white ball top and to cover the whole with a hemispherical glass bowl provided with reference marks. The axis of this top tries to remain vertical despite tilts of the aeroplane, or accelerations; it does not quite achieve this object, but for small and not too continuous acceleration it makes a passably good attempt. The instrument is used in clouds as follows:— The top is placed so that the pilot can look down on the hemispherical glass bowl which swings with the aeroplane. The top axis remains approximately vertical, and hence, when the aeroplane tilts, it appears to the pilot to move in the bowl. If the pilot follows the apparent movement of the ball on the top axis with his stick, he makes the correct movements to restore his machine to a level position; this is easily verified. When the aeroplane is kept on an even keel, as explained above, turning is indicated on the cross bubble level and is therefore easily prevented by the use of the rudder.

51. This instrument has two great advantages that particularly fit it for use in light unstable aeroplanes. These are:—

1. Its indications are instantaneous.
2. It indicates fore and aft level as well as lateral level.

The latter is an important point in unstable or untrimmed aeroplanes, since, in the absence of the horizon, such an aeroplane is very difficult to control fore and aft, because variations of the speed indicator do not begin to show until the nose has been up or down for some little time. In stable aircraft, that can be trimmed fore and aft, this is a matter of minor importance only.

52. The chief defect of the instruments is that violent manœuvres upset it altogether and hence it is of no help in regaining control after control has once been lost. There were also, I believe, difficulties with the pivot, but probably

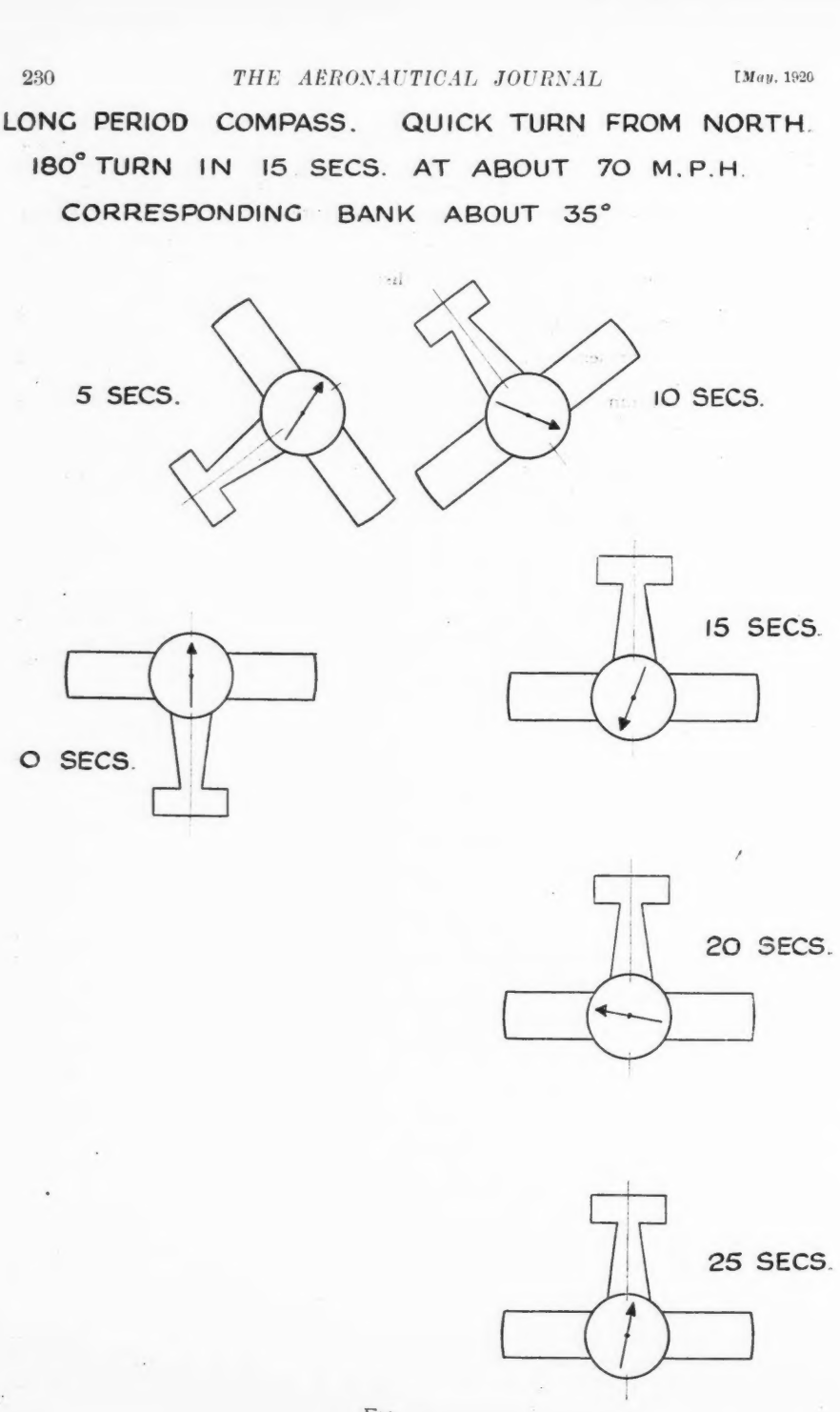

LONG PERIOD COMPASS. QUICK TURN FROM NORTH.
180° TURN IN 15 SECS. AT ABOUT 70 M.P.H.
CORRESPONDING BANK ABOUT 35°
5 SECS.
10 SECS.
15 SECS.
0 SECS.
20 SECS.
25 SECS.

FIG. 4.

SHORT PERIOD COMPASS. QUICK TURN FROM NORTH
180° TURN IN 15 SECS. AT ABOUT 70 M.P.H.
CORRESPONDING BANK ABOUT 35°

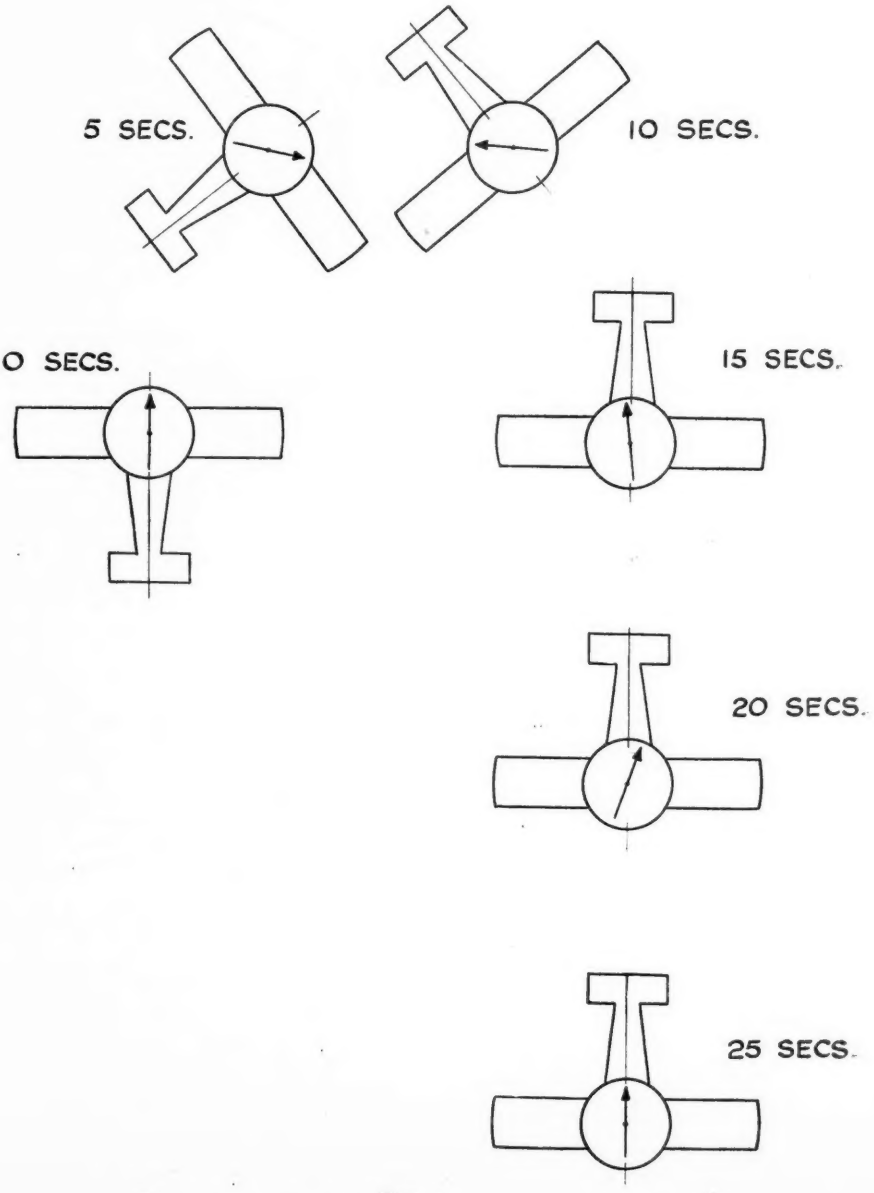


FIG. 4.

these have been overcome by now. Apart from these defects the instrument undoubtedly makes cloud flying comparatively simple with very little previous training. Clearly it does not, by itself, provide the absolute safety required for commercial work, and it is ruled out for fighting aeroplanes by the fact that it cannot stand "stunts."

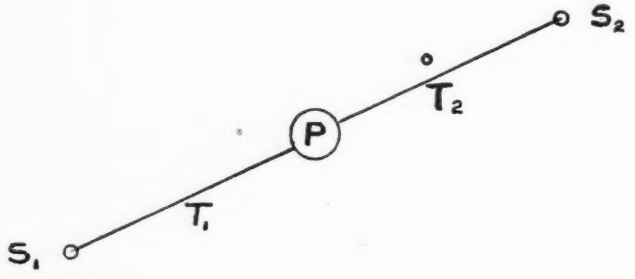


FIG. 5.

Gyro Turn Indicator.

53. The Gyro Turn Indicator developed by the R.A.E. from a similar device by Professor Henderson for use in ships, provides, to my mind, the best instrument for all round use. This consists of a gyro wheel spun directly by the air flow past the aeroplane. The axis of spin is fore and aft, and the whole is able to precess about a thwartship axis. The precession is controlled by relatively strong springs and its deflection against these springs is magnified and read on a dial, the deflection being proportional to the rate of turning in space. The chief merits of this instrument are:—

1. Its extreme simplicity and coarseness of construction, owing to the forces involved being so large that no delicate parts are necessary. It is therefore very reliable.
2. No amount of stunting puts it off its good behaviour so that it is available to regain control at any time after control has been lost.
3. It is almost instantaneous in action, registering even a small turn the moment it begins and before any appreciable turn has taken place. For this reason it can be used as the primary straight flying instrument and the compass returned to its proper sphere of duty, that of an instrument to tell one from time to time where one is going.

54. With this instrument cloud flying on a machine that is stable and trimable fore and aft should be perfectly simple and require no more training than is required to give the pilot confidence in his instruments. With it the compass is not required to register turns correctly on a north course, but it should be of good behaviour in bad bumps.

55. Summarising the situation with regard to the operation of flying through clouds, I think it is possible to state quite definitely that, whilst cloud flying without special instruments is a difficult and dangerous operation, unsuited to commercial work, yet there are three distinct and tried forms of apparatus that make it feasible, and one at least of these, the Gyro Turn Indicator, whilst being simple, reliable and cheap, makes cloud flying practically as safe as open air flying, apart, of course, from the question of collision which we will consider later.

Danger of the Clouds Coming to Earth whilst the Aeroplane is Above Them.

We now turn from the actual passage through the cloud, which we have seen to be feasible, to the most serious difficulty of all, the danger that whilst

above, or in the clouds, the clouds themselves may come down to the ground. If this occurs without the pilot being aware of it, disaster on trying to land is practically inevitable; until this danger is satisfactorily overcome, over-cloud flying, of the type we are considering, is emphatically not a commercial proposition.

So far as I can see there is only one counter for this danger, and that lies in the use of the wireless telephone together with an organisation that keeps the pilot informed of the state of the air under the clouds during almost the whole flight. I do not myself think that any means of communication short of direct speech on the telephone will be adequate for this purpose, on account of the complicated ideas that may have to be conveyed. It may, for instance, be necessary to tell the pilot that he cannot land at Hendon, but that at Croydon aerodrome the air is clear enough to get down; or, again, that London is totally mist-covered and a descent should be made at Lympne or some other aerodrome short of London.

The organisation that I should imagine for this purpose would consist of a train of small wireless stations along the route, at such distances, that one at least would be in communication by wireless telephone with the aeroplane during the whole flight. These stations would be linked by wire with the aerodromes along the route and with the Meteorological Office. One might hazard a guess at 100 mile intervals, with perhaps intermediate observation huts at shorter intervals, the latter connected with the main wire, but not equipped with wireless. These intermediate stations would be manned on cloudy days only and would then report to the main stations when any dangerous lowering of the clouds in their area occurred.

With such a train of stations it should at least be possible to ensure that nothing short of complete engine failure should necessitate landing in fog. This would be a great step forward, because, in any case, commercial aeronautics is going to depend on forced landings being reduced to a negligible quantity. The forced landing due to a defective engine, when it does occur, presents, however, a serious difficulty on account of the fact that, although the ground at the wireless stations may be clear, the ground at the position of the forced landings may not be clear. It is mainly for this reason that the intermediate observation huts might be required; it might, by their use, be possible to keep the pilots informed of any districts on their routes that were extensively covered, so that if their engines failed they could use their height to get away from the danger areas. It must be remembered that the aeroplane, when over clouds, will generally be above 10,000 feet and hence will have a circular area of about 12 miles radius from which to choose a landing ground; probably days on which the fog patches are more than 24 miles across will be considered unflyable in any case. The problem of how the pilot is to know where he is when his engine fails is dealt with later.

Difficulty of Navigation.

Navigation over clouds can conceivably be carried out by one of several methods. These methods might be grouped under the following heads:—

1. Dead reckoning.
2. Observation of heavenly bodies.
3. By direct observation of fixed balloons or Archie bursts.
4. By the help of wireless.

Dead reckoning has been shown to give results that with great care can generally be relied upon to within about 10 miles in a hundred. But until meteorology has made very great strides, I do not think that one will be able to *rely* for commercial purposes on unassisted dead reckoning over distances greater than about 100 miles; one has to be so very reliable for commercial success. Dead reckoning for some distance will always be a part of any system of naviga-

tion out of sight of land, but alone, it is not adequate for the purpose under consideration.

Observation of heavenly bodies looks very promising in connection with very long voyages, particularly over sea or over unmapped country, but it is rather too cumbersome a method for use in relatively short flights of 200 to 500 miles, such as I have in mind in this paper. At the best this method of obtaining one's position does not look likely to give results much better than from within 5 to 10 miles; this accuracy is amply good enough for general purposes, say when crossing the Atlantic, but it is not very much help when the aerodrome has finally to be found in thick weather under clouds.

The use of observation points such as balloons or archies have the great disadvantage that in the former case there is a horrible wire passing up through the clouds, and in the latter case there is hard and heavy shell to be got up through the cloud without hitting anything and to be brought down to earth again without damaging life or property.

The remaining method is by wireless. There are really four separate ways of using wireless:—

1. With large central stations, not necessarily on the route, receiving signals directionally from the aircraft and themselves working out its position and transmitting back to the aircraft.
2. With large beacon stations whose messages are received directionally on the aeroplane, the position being worked out on board.
3. With small beacon stations on the route whose signals are received directionally by the aeroplane with a fixed apparatus that allows the pilot to fly straight on the beacon.
4. With small direction receiving stations on the route that receive the aeroplane signals directionally and instruct the aeroplane accordingly.

Each system will probably have its special use, but for the purpose in hand only the last is, in my opinion, likely to yield good results.

An objection to 1 lies in the large size of the transmitter required on the aeroplane.

An objection to 2 is the special knowledge and apparatus required in the crew.

The objections to 3 are not so serious, and it might be a good competitor with 4, but for the fact that we have already come to the conclusion, on other grounds, that the aeroplane must be equipped with a wireless telephone set.

If, as I have tried to show, the wireless telephone, in communication with a series of stations on the route, is a necessity for reasons of safety, then it seems to me that the following system of navigation coming under the fourth head possesses the most general advantages.

Imagine a much-frequented trade route, say from London to Paris, or London to Scotland or Ireland, and suppose that at the termini and at distances of say 100 miles there were stations equipped with wireless telephones and directional receiving sets; suppose also that the aircraft are equipped only with the wireless telephone transmitter and receiver. The course of a flight might be as follows:—

The aircraft starts from London with the best available information as to wind above clouds and state of the air below clouds along the route. The pilot immediately passes up through the clouds on the best course he can lay to get him to the first wireless station, say Folkestone. Let us imagine that his dead reckoning would have brought him within 15 miles to the west of Folkestone, although of course he does not know this. When about twenty miles or more short of Folkestone, by his calculations, he calls up on his 'phone and asks for his bearings. Two alternative procedures are now

possible. In the first the operator at Folkestone gives the bearing to the pilot from his station, and the pilot flies on the reverse of this bearing and ultimately, with a few corrections from the ground operator, arrives over the operator and is informed of this fact; the operator can tell this moment approximately by the fact that the signals become indeterminate, or perhaps by the use of a direction finder with vertical motion. In the second procedure the pilot holds his course, and the ground operator estimates his shortest distance from his station by the maximum rate of traverse of his signals and a rough knowledge of his ground speed. In either case the pilot, without descending through the clouds, gets his position fairly accurately every hundred miles or so and carries on in between by means of dead reckoning. He is also of course kept informed, by the intermediate and terminal stations, of any serious meteorological change or impending change, either in wind above clouds or in the conditions below the clouds along the route.

Taking into consideration the argument that the telephone on the aeroplane is a practical necessity for over-cloud flying, it seems to me that some such method as that outlined above will provide the best means of navigation on much frequented routes, principally because it calls for a minimum of apparatus and technical skill in the pilot. All he requires is the ability to use a wireless telephone set and to lay a course for a short flight by dead reckoning. The directional wireless set is in the hands of a specialist, to whom wireless and not flying is the primary fact of life, and who is sitting in comfort in an office on the ground.

The meteorological problem of obtaining the wind above the clouds, with sufficient accuracy for the intermediate dead reckoning, introduces a difficulty, but not an impossibility; probably the most satisfactory method of obtaining the necessary data would be to use self-recording apparatus elevated by kite balloons situated permanently in areas prohibited for flying. There are other methods of obtaining this data, such as the observation by aeroplanes, of A.A. fire above the clouds, or again by the use of sound ranging on explosive signals carried by small free balloons. To all these methods there are objections, but it must be remembered that the high altitude winds do not vary rapidly with space, and hence it is possible to put the wind finding stations in unfrequented spots at considerable distances from the actual routes.

No doubt the actual observation at the control stations of the prevalent errors on any particular day would greatly assist in keeping the official wind at any height in agreement with the true facts. It might even be possible to develop some method of obtaining the wind in the first place by an observation of error in a very carefully flown course by a special aeroplane.

Minor Difficulties of Over-Cloud Flying.

Difficulty of Locating the Aerodrome at the End of the Flight.

Anyone who has tried it will realise how difficult it is to locate one's position when plumped down out of the clouds at an unknown spot on a day of low visibility. To locate oneself with reasonable rapidity under these conditions requires a very intimate knowledge of the details of the country. For this reason it would be a very great drawback to over-cloud flying if the final descent through the clouds were to occur at an indeterminate position that may possibly be several miles from the aerodrome.

With an aircraft equipped with the telephone, and with a traffic controller at the aerodrome equipped with directional wireless, this difficulty would practically disappear; for the traffic controller could actually lead the aircraft home even whilst passing through the cloud and could continue to lead it until within sight of the aerodrome.

Danger of Collision in Clouds.

Except in the case of forced landings the aeroplane will only be in clouds when descending to, or rising from, the aerodrome. With heavy traffic continually passing up and down through the clouds over the aerodrome collisions are inevitable unless some central control is exercised. I believe that the only way in which this control can be managed is by the wireless telephone assisted by directional wireless receivers on the aerodrome. With this apparatus the aerodrome traffic controller could ensure that only a safe number of aeroplanes were in the clouds together and could have some idea of their relative positions. The in-coming aeroplanes might, for example, be kept on the down-wind side and the out-going on the up-wind side of the aerodrome, so as to avoid confusion. The traffic controller at a large aerodrome would hold a very responsible position; he would be somewhat like a mixture between a railway signalman and a harbour master.

Difficulty of having to Fly Very High Occasionally to Clear Clouds.

There are days when the clouds reach a height that it would be inconvenient to have to reach in an aeroplane, both on account of discomfort of passengers and pilot and of the great power reserve required to reach such a height. Again there will be days when the adverse winds at the height necessary to clear the clouds would be too strong to make the flight practicable.

On such days one must of course in any case fly below the clouds and put up with the discomfort; it is not contended that it will always be possible to fly above clouds, but only that it will often be possible to do so with advantage. On days of high wind, of course, aeroplanes passing in one direction would keep below clouds, whilst those going in the contrary direction would fly above them. Even flying below clouds, however, the directing stations would be of considerable value in bad weather.

Danger from Storm Clouds.

It is possible that storm clouds might form whilst an aeroplane is actually above clouds and that the electrical disturbances might interrupt communication with the ground. I do not know what are the possibilities of this occurring; perhaps some meteorological expert will tell us to-night. If the danger is serious, then it would throw another burden on the meteorologist; he would have to predict these occurrences in time to prevent serious harm. On such a state of affairs being predicted all aeroplanes would be brought down by wireless signal and made to finish their journey in discomfort beneath the clouds.

General Considerations.

If I have succeeded in making myself clear to-night I have indicated that in my opinion the development of over-cloud flying is probably essential to the full commercial use of aviation in this country, and that to develop over-cloud flying a good deal of organisation on a large scale is necessary. This organisation can be divided into three main groups:—

Meteorological, consisting of the continuous determination of wind above clouds and of the height of the top of the clouds, etc.

Constructional, in the laying down of wireless control stations at and between termini, on the main routes.

Instrumental and Training, in the provisions of the necessary instruments for cloud flying and dead reckoning, and in the training of pilots in their use.

With regard to meteorological organisation, the first step is obviously to push on with the development of methods of recording the upper winds even when

clouds are present, since without this information dead reckoning over clouds is impossible. I believe this step is of great importance to the development of commercial flying—quite apart from over-cloud flying—because the knowledge of the wind force and direction at various heights is obviously going to be of great economic importance, and it will be a serious handicap if this information can only be obtained after the clouds have cleared, having regard to the inevitable delay that must occur between the obtaining of the information and its reaching the aerodrome at which it is required. How much more valuable would such information be if it were continuous both in clouded and clear weather so that immediate advantage could be taken by the pilots of a sudden clear up?

Of the various methods briefly indicated in the body of this paper I incline to the kite balloon with recording instruments. For by this method continuous records of the conditions at any desired number of heights can be obtained with no delay whatever. The necessary instruments have already, I believe, been brought to a fairly advanced stage at the R.A.E.

The organisation of the control stations suggested is of course a large undertaking. Ultimately I see in imagination a state in which the British Isles might be dotted over with such stations, exactly as at present the coasts are dotted with lighthouses. If this vision were ever realised there would be no difficulty at all in arriving on long flights from great distances, say by airship from America, and finding the earth covered by cloud. One would be certain to pick up some station, obtain position and a general report on the weather conditions below clouds, and be passed on from station to station until the terminus was reached.

This, perhaps, is peeping rather far into the future; such a system must start from small beginnings, say the laying down of one or two main routes radiating from London. Whether this should be undertaken by the Government or a combine of firms is not in my power to say.

With regard to the question of instruments and training of pilots. The instruments have passed the scientific development stage as far as flying in clouds is concerned and now only require general application. Whether the wireless directional and telephone sets have also passed the development stage, I am unable to say—perhaps someone in the audience will tell us in the discussion.

The training of pilots amounts to little more than teaching them to use and believe in their instruments. Flying in cloud is a purely instrumental operation and some experience is generally needed to convince a good open air pilot of this fact. As already stated we succeeded at Orfordness in training formations of pilots of only moderate experience to fly through clouds in formation, even without the turn indicators; if this was possible there should be little difficulty in training pilots to climb through clouds without the embarrassment of a formation of other machines in the neighbourhood and with the help of the gyro turn indicators.

Conclusion.

In conclusion, I will only say that if the arguments I have put forward are correct, then some arrangement whereby our commercial pilots are enabled to fly in safety over clouds, when they deem it expedient, is almost a necessity to the full development of commercial aviation in this country. I have tried to show that the apparatus and method of training by which this could be done is already in existence, but that a very extensive organisation of these resources is necessary to make over-cloud flying sufficiently safe and reliable for commercial purposes.

The first steps towards the realisation of any such scheme as has been sketched out in this paper would of course be the laying down of an experimental route—say London to Paris—and a vigorous development of the meteorological organisation necessary to obtain wind at great heights, over clouds when necessary, and to determine how often the top of the clouds, in winter, are too high for economical flight above them.

DISCUSSION.

Colonel BEATTY said with regard to the practicability from the commercial point of view of flying above clouds beginning with climbing through clouds and continuing above them, that it would probably pay to make the passengers more comfortable and take advantage of the wind in this way if no draw-back were brought in at the same time. He had no doubt that the passengers would prefer flying above clouds, as he had seen them arrive looking very sorry for themselves after flying under the clouds. With proper meteorological information one could also take advantage of the wind, and he personally believed that if pilots would believe what the meteorologists told them they already had reliable information now-a-days as regarded the strength of the wind and the height at which they could fly. He did not see any advantage in flying at too great heights as it made the passengers cold. It was only when one could fly above comparatively low clouds that it would pay to do it commercially. On some occasions one could not get over the clouds even by a 15,000 foot climb, and he had heard of their reaching 30,000 feet, but not of anyone climbing over them at that height. Flying above clouds was purely a question of the training of the pilot and good meteorological information. He did not think it at all impracticable. The instruments available at present for climbing through clouds commercially were not adequate. The air speed indicators and pitot tube type of static turn indicators were useless in a wet, cold cloud, and in these conditions the compass became one's only friend, though the lecturer did not refer to it very kindly. Used as a level it comforted the pilot very much. In commercial flying it was necessary that the pilot should know the route well and not require landmarks near the aerodrome. With good meteorological information the strain on the pilot would be rather less above clouds, but he would prefer to go underneath without good meteorological information. It would be better to see what one was flying into. He thought the beauties of above-cloud flying had had rather too much stress laid upon them. The lecturer had not mentioned the dazzle and glare which were most objectionable after a while.

Capt. CARTER said in regard to the London-Paris service, suppose one were flying on a day when the clouds were at 500 feet. He went above them to 4,000 or 5,000 feet, set his bearing for Paris, and flew for 2¼ or 2½ hours, and then came down. How did he know where he was exactly? With regard to directional wireless along the route, if a pilot went up from London and flew for, say, an hour and a quarter, it would take him over the Channel. He received from the wireless station on the French side information that no station had reported that there was a height of 300 feet between the cloud and the ground. (The Lecturer: He had better come back.) That situation had arisen on several occasions. The weather had gone down in the Channel, and on both sides of the Channel, inside 20 minutes. From the commercial point of view was it worth while that passengers should go up above the clouds under those circumstances? In case of necessity of a forced landing—which was serious in the case of a two-engine machine—would it be better to come down from above the clouds—from 5,000 feet—or to land after having watched the ground for half an hour at 500 feet? The turn indicator, he believed, was capable of adjustment in many ways. In actual experience it was found that it only showed the slightest movement of the rudder from left to right. If the least bank was put on the machine the turn indicator went off the scale.

Major DOBSON said an instrument was in existence for use on kite balloons for getting wind and other data, but the kite balloon had to be hauled down to get the information. Work was being done on another instrument which recorded on the ground, the kite balloon being kept up as long as it would remain inflated. The possibility of getting any such instrument into actual use was apparently

very remote at present, so that in view of other urgent work it was not being pressed forward, though the main scheme was complete.

The clouds coming down to the ground seemed an insuperable difficulty. The country generally might have 500 feet clear of cloud, but a pilot might have a forced landing while flying over high ground. He did not see any means of avoiding that altogether. As regarded landing, a number of people had the idea that if one could get an instrument which would show the pilot his height above the ground, landing in a fog or cloud would be more or less safe. What the pilot really wanted was to know what obstructions there were two or three hundred yards ahead of him.

A pilot of the Aircraft Transport and Travel Company referred to finding the R.A.E. Gyro Turn Indicator too sensitive. Recent conversation with one of their representatives showed that some spare parts had got lost in the post. Only the spring which was in the instrument when it left Farnborough arrived, and the stronger springs were lost. The latest form of Gyro Turn Indicator had a completely adjustable sensitivity which the pilot could alter in the air through 600 per cent. range by pushing a lever round with his thumb. He thought the instrument would be sufficiently insensitive for flying in clouds on a scout, as well as being sensitive enough for taking sextant observations when flying above clouds on a slow machine like a Handley-Page.

Major TOMLINSON said during the war wireless apparatus was produced which was sufficiently reliable for work they had at that time, but the conditions now demanded rather more, and the apparatus was not really what was wanted. It should be remembered that attending to the wireless apparatus was now only one of many things done by the same man, whereas in the war it was possible to put it into the hands of a highly trained man with nothing else to do but work it. He thought the lecturer's scheme for directional wireless was quite a sound one. It was a little difficult to work on a single bearing. During the war they had two bearings, which fixed one's position much better, but a single bearing would be a great help. Few routes at present were being flown over sufficiently to warrant the expense of ground stations, but the time would come when such ground stations would be essential. The wireless telephone was the most useful form of communication, because it did not require knowledge of Morse transmission and reception. Many of our air routes, however, only began after one left this country, and that was a slight difficulty for telephoning. It would be overcome by the exchange of operators and so on. Direction finding during the war was done to a great extent by wireless, but, as far as he knew, on the civil routes at present there was no directional wireless. As the lecturer said, wireless, when thoroughly organised, would make flying much safer and perhaps possible under conditions where it was now impossible.

Air Commander R. BROOKE-POPHAM thought there was a tendency to give too many instruments to pilots. One should try and reduce the number of things pilots had to watch in the clouds. He had done very little cloud flying, but on the few occasions he had tried it he got on a stable machine and left go of everything except the rudder. Eliminating one of the three functions—lateral control, longitudinal direction and directional control—and leaving the pilot only two to deal with and two sets of instruments, would be more of a help for cloud flying than elaborating the instruments. He thought that an instrument recording the height above ground level, referred to by Major Dobson, would be an enormous help, if only for the confidence it would give to a pilot, but he did not know of anything in sight towards solving that—nothing that was a practical solution. Instruments should, if possible, communicate to the pilot what was happening to his machine straight away without his having to translate movement of the instrument in his brain, and deduce from that what the machine was doing. He had in mind an arrangement he had once

in a machine consisting of two U-tubes, and when the right hand one was higher than the left hand one, the pilot was supposed to remember that the machine was turning to the right.

Capt. DOUGLAS said it was pleasanter flying above clouds, and he always flew above rather than below. One could get up 2,000 or 3,000 feet with the compass alone, and it did not take long. The trouble in commercial flying was that one had first to know that he could get above them, and then to know what he was going to meet at the other end. That was a question of meteorological organisation. In rainy weather one might not get above them even by going up 10,000 or 12,000 feet. Inland, with a cold westerly or north-westerly wind, the clouds never came down. In the Channel, if there were a wind blowing up the Channel, one might suddenly come over the high ground. He had read in the "Financial News" that evening of a pilot and passenger who had an unpleasant experience in fog in the Channel. It was fine in France except within about five miles of the Channel. If they had managed to get over the clouds, which were not more than 2,000 feet thick, they would have been bound to strike fine weather. A R.A.F. pilot who crashed last May when flying to Boulogne in a fog would have seen that it was fine in France if he had got above the clouds. The matter depended largely on meteorological organisation. When commercial flying was more general it might pay to provide the organisation. It was unpleasant to have a forced landing through clouds, but if one had a failure under the clouds and over the sea it was as bad as above the clouds.

Wing Commander WARRINGTON-MORRIS said the Lecturer proposed to throw all sextants overboard, but good work had been done by sextants. He also proposed to have relays of wireless stations at 50 miles apart, but that did not cater for long-distance flights over the sea. (The Lecturer: I only referred to the shorter routes; I have remarked in the Paper that the sextant is a good thing for long routes.) On the Boulogne to Cologne route stations were put up for giving the weather conditions to aircraft by wireless telephony, and were extraordinarily useful. The directional side of the wireless organisation on this route was not completed before it was packed up. The ordinary D.F. ground work from stations had been used for a long time, and had, as a rule, been very accurate, especially where there were two or three stations to fix positions. But it was not entirely accurate on all occasions. At different times of the day and night and on different wave-lengths there were certain errors. Directional wireless in machines was good if an operator could be carried. The solution he thought was to have all three things: air control stations and ground directional wireless for short routes, directional wireless in machines for long routes, sextants and artificial horizons for oversea routes.

Major HECKSTALL SMITH said it was an opportune moment to rub in the necessity for recognising the value to the country of spending more money on research. This lecture had shown almost more than any previous lecture the possibilities of aircraft under adverse conditions. It was often forgotten or not understood that the production of wealth had no relation to the saving of "Bradburys," and the past had proved how great could be the wealth produced by advancement in methods of transport. It was a comforting thing to think that this country had a few scientific men like Professor Jones and other scientists who had spoken to-night, who had given so much attention and done such a vast amount of valuable work on the subject, and there should be more money at the disposal of those gentlemen, so that they could carry on and continue the line of work they had pursued prior to and during the war.

Mr. R. B. BOURDILLON (ex-R.A.F.) said he had found the gyrostatic turn indicator very useful and had had no trouble with it even when doing Immelmann turns and spins in bumpy snow clouds. With this instrument it was easy to keep control or even to fly on a northerly course in any cloud. After trying

various forms of static head turn indicators, it was most refreshing to have the gyro indicator. If adjusted in its most sensitive form it was a little surprising at first, but one got used to it in half an hour. There were two types of days when over-cloud flying was important. One was when it was obviously going to be fine weather for several hours with the clouds never below 1,000 feet, and from the general weather conditions one felt fairly sure of finding the ground clear on arrival. In this type of weather over-cloud flying was safe and pleasanter than under-cloud flying. He disagreed with Col. Beatty's remarks on the glare above clouds, and had found that most passengers greatly enjoyed over-cloud flying. The other type of day was that on which pilots could not be certain that the clouds would not come down to the ground. Then over-cloud flying was dangerous and unprofitable. Wireless was not sufficiently developed to be very reliable yet, and the solution of the problem on bad days seemed to be rather the possibility of dispersal of fog or clouds, or the provision of very large areas in which pilots could come down. Had the Lecturer any reports to make on fog dispersal? He understood something had been done fairly recently.

Mr. J. R. PANNELL said he should like to emphasise the importance of direct measurement of height. It was, as Mr. Dobson had pointed out, of no use attempting to land an aircraft in a ground fog by relying on a measurement of height, unless one could be sure of a sufficiently large landing ground free from obstructions. But one can imagine a pilot being caught in fog wishing to come down and hoping to find clear air near the ground. There would be a certain height at which the aircraft was safe from obstructions; but with the present inaccurate methods of measuring height it would be necessary to allow a considerable margin for safety, and that margin might result in the pilot failing to find clear air.

So far as he was aware the only means for height measurement employed in practice on aircraft was the use of an altimeter, a method which was open to serious objection. In the first place the instrument measured *pressure*, the dial being calibrated for altitude on the assumption of an average distribution of pressure in the atmosphere. The instrument is set to zero on leaving the ground, but on landing the pressure at ground level may be different, due to either of the following causes:—

(a) change in the barometric pressure with time or locality.
(b) if the landing is made at another aerodrome, due to the different elevation of the landing ground.

In a flight of 24 hours' duration the former cause might easily result in an error of 300 feet in the reading of the altimeter. This error can be allowed for if the barometric reading can be communicated to the aircraft before landing. It may also be noted that an independent knowledge of height would enable a record of barometric variations to be kept *on the aircraft*; such a record would be of great value on a continuous voyage such as an airship might take, lasting several days.

The second chief source of error is instrumental, and due to the hysteresis of the metal diaphragm of the altimeter. A flight of two hours' duration at 10,000 feet followed by a descent to the ground in 15 minutes would, due to hysteresis, probably result in the altimeter reading about 100 feet at ground level.

A direct measurement of height would therefore be of great value; perhaps Prof. Jones could tell them if any advance had been made in that direction? It had been proposed to measure the time taken for a signal from the aircraft to be reflected from the earth, but the problem was evidently a difficult one.

General Sir SEFTON BRANCKER said that the spice of life was its variety, and he was filled with joy to think that the learned Professor was when he

last saw him a humble Captain in the Air Force and had to stand at attention and salute. Prof. Jones was one of that little group of scientists to whom aviation owed a debt that could never be repaid. He and certain others of real scientific attainments came into the Air Force and gave their services unhesitatingly, and he never met braver men in the air either as pilots or observers. They put the danger aside and thought of nothing but progress and improving the conditions governing the use of aircraft. We have two great enemies in commercial aviation—finance and weather. Finance is a rude, unpleasant gentleman; the burning question was whether the Government was going to preserve aviation or not. The weather was rather a charming, coy and hard-to-please person, with whom it was a pleasure to deal. The progress of civilisation had always been a struggle between mankind and nature. We were now up against nature again in her most primitive form. Generally, he was in cordial agreement with the Lecturer. The only thing he did not like was his lurid description of the terrors of cloud flying. He (Gen. Brancker) was a pretty bad pilot, and he never attempted stunts except in the privacy of a cloud, from which he sometimes involuntarily came out in most improper attitudes. Really the ordinary cloud was a very harmless thing to deal with, but the real storm cloud was a danger. The two things to compete with it were instruments and stability. He was a great believer in instruments. If one had reliable instruments they would not let him down. He was very much in favour of some form of instrument which would tell a pilot his height above the ground. It would be a godsend when coming down through thick fog or cloud to about 20 feet, and would give a pilot plenty of time to get up again without hitting anything if it was impossible to land. Weather was the most limiting factor to commercial aviation in this country. Except for finance and weather one could run as regularly as clockwork and as well as, if not better than, any train and steamer. Possibly the weather was a blessing in disguise, for it had produced in England a fearlessness which existed in no other country. He was very much in favour of what Gen. Brooke-Popham said about stability. The B2C before the war was the most stable machine produced, and that stability had not again been reached. In the war quick manœuvring was necessary, and it was thought impossible to obtain this with absolute stability. We must get back to absolute stability, so that an aeroplane when let go would take care of herself. The less a stable aeroplane was interfered with in a cloud the better. One should be able to keep straight with a compass and turn indicator, and not interfere in any other way. When a stable aeroplane lost its stability in a cloud the pilot must be holding hard on to the controls. There were two schools of thought in aerial navigation. On the old C.A.T.C. Committee he was a supporter of free navigation. That meant that at one's post of starting (now Hounslow) one had accurate weather information and the pilot saw the map and decided which way he would go and whether he would fly under or over the bad weather. He held to that theory for a bit, but later he (Gen. Brancker) came back to the other school of thought. That was to paint a white line across the country with frequent landing places and to fly an absolutely dead course along them and never go over the clouds if it could be avoided. But since the war he had had some experience of the French route and had begun to veer round to the old idea again. Such a system of navigation must, of course, be assisted with instruments and organisation. Pilots were most conservative people. Once they did a thing one way they would not believe it possible to do it another. The turn indicator was reported "dud" at first sight. The biggest progress made during the war was in the confidence of the public in flying and in what the average pilot could and would do. On Salisbury Plain it used to be an act of heroism to fly over the Avon or the hills at Tidworth, but a year later the same machines were being flown and nobody thought anything of going anywhere with them. With regard to the Zeppelins, he was one of the radicals who said that we should have to fly aeroplanes at night and attack the Zeppelins with Camels and Scouts and other

machines, and, although the idea was ridiculed at first, it was subsequently adopted. Pilots would soon laugh at the weather and go right off through the clouds without hesitation, but they must be assisted by improved design, instruments and organisation. With regard to the London-Paris service that route was, in a way, one of the most difficult, but one quality that made it easier than other parts of the world was that there were no mountains en route. The poor little hills just south of London—perhaps they went up to 500 feet—were the biggest obstacle between London and Paris. When the clouds were down on them the pilots, who would fly under the clouds, found the clouds down on the hills and could not get on if they were not prepared to fly through and over the clouds. The weather reporting system was only in embryo, and there were no wireless telephones to tell pilots what the weather was like on the other side, and sometimes such weather necessitated coming back. When a wireless telephone service was organised they would be informed if the weather was bright on the other side and the height of the clouds. On the big routes, such as those to Constantinople, India and Africa, the real mountain ranges would cause trouble even in the best weather, as the tops of the hills were often in heavy clouds, very bumpy, and there were often thunderstorms to compete with. Storm clouds on the mountains and fog down to the ground were the two difficult factors for flying in the future. Organisation, including the provision of accurate and rapid weather reports, wireless for navigational and information purposes, and general organisation of the personnel, was the life blood of commercial aviation. He was in favour of the use of wireless on the lighthouse system. If pilots were allowed to begin talking to the ground, the air would be full of messages, and he imagined that would not tend to good navigation. Messages should be sent to the pilot at definite intervals, and the pilot should not be allowed to talk unless it was a case of S.O.S. or some emergency. In regard to the Lecturer's question, "Does it pay?" the answer was in the negative—not a penny!*

Mr. E. G. WALKER: Although the point which I wish to raise is not directly concerned with flying over clouds, I have no diffidence in raising it, inasmuch as Prof. Jones specifically refers to it in his Paper, and it was also referred to by one of the speakers in the discussion. I refer to the possibilities of utilising kite balloons for obtaining the necessary meteorological data which is required for over-cloud flying.

In the past considerable objection has been raised to the use of kite balloons for meteorological work by reason of the obstruction caused by the kite balloon cable, and therefore there has been a great tendency to rely entirely upon the information supplied by aeroplanes. It is reasonably certain that given an instrument equipment of the same reliability, better and more complete information can be obtained by means of instruments mounted on a kite balloon than by those mounted on an aeroplane, simply because the balloon is stationary and the aeroplane is not. The objection to the use of balloons in areas that are likely to be much frequented by moving aircraft is a fairly serious one, as it is a matter of considerable difficulty to mark the cable out in such a way that it is very easily seen under all conditions.

I am uncertain exactly how far apart it would be necessary to make observations for reliable weather prediction below the clouds, but I conclude that considerably more stations would be required than the three or four mentioned by Prof. Jones for above-cloud work. If it is definitely agreed that owing to the steadier conditions obtaining at high altitudes observations at so small a number of stations are all that are required, the prime objection to the use of balloons is removed practically entirely, for there is no reason why Prof.

* General Brancker points out that his answer to the question "Does it pay?" applies only to the present time. Commercial aviation will pay all right in the future, and it is for Government to help it over the lean years through which it has to pass before that time.

Jones' suggestion that the balloon should be put up only within prohibited areas should not be adopted, for the number of prohibited areas throughout the country will probably be more than the number of observation stations required. The drawback is that the prohibited areas will not be distributed over the country from meteorological considerations, and so presumably it would be necessary to put certain balloons in areas which were not prohibited. Probably the number of these cases would be so small as to make it possible to devise special arrangements to suit.

The maximum height at which observations are required is not, so far as the writer is aware, stated in the Paper, nor has it been referred to in the subsequent discussion. Presumably this height depends principally upon the ordinary heights to which clouds rise under normal conditions. Captive balloons which have been used during the war have, of course, only been flown at relatively low heights, but for special purposes it has been possible to design and construct balloons capable of reaching 16,000 feet. I believe it to be possible to reach still greater heights without encountering any insuperable difficulty in design, construction or operation of the balloons. Furthermore, under peace-time conditions it will be possible to give these balloons better gas holding properties than has hitherto been done, and so it should be possible to keep them in the air for a relatively long period. One of the great advantages possessed by the kite balloon for aerial observation during the war was the ability of the ordinary observation balloon to stay in the air several days on end without having to be topped up. The fact that high altitude balloons have not hitherto been so successful in this respect has simply been due to the impossibility of obtaining the most suitable material for their construction during the war.

The successful design of high altitude balloons for meteorological work will involve the solution of a certain number of new problems and particularly will require some advance in the design of cables. The writer believes it to be possible, without having to undertake an abnormal amount of investigation and research, to arrive at a suitable type of cable which will allow of the readings of meteorological instruments suspended from a balloon at any height which is possible for commercial flying, to be registered on the ground continuously, and that it will only be necessary to haul the balloon down at intervals of several days as a minimum. Measurements of all the atmospheric conditions, particularly of wind speed and direction, will be most simply and reliably made by this means, and it may reasonably be assumed that the reliability of the information obtained will be much greater and the cost of getting it much less than by any other means that can be adopted.

The writer does not know what amount of experiment and research is necessary for developing self-recording instruments which are able to transmit electrically over such distances as would be required for this type of work, and so does not venture an opinion on this point, but he believes the amount of work required to develop the appropriate type of balloon and cored cable would not be great. If high altitude flying is to become a commercial proposition in the future it will certainly pay to get on with this work and develop the high altitude meteorological kite balloon as being the best means of getting the necessary data for safe flying.

LECTURER'S REPLY.

I have listened to the discussion on my Paper with the greatest interest, because the positions and occupations of those taking part are such as to give their opinions and the views they put forward the very greatest weight, every speaker, I think, without exception, being an acknowledged authority upon the subject on which he spoke.

I will attempt first to review the general trend of the discussion and then to answer in detail any remaining points raised by the individual speakers.

All the speakers appeared to be in agreement with regard to the discomfort of flying under clouds and the relative comfort and pleasure of flying above them, and all agreed that if it were not for the danger at present connected with flying over clouds it would be the obvious way of dealing with bad weather, except when the top surface is too high for practical flying. Again, there was general agreement that both the present organisation and the present instruments commercially available are inadequate for routine flying over clouds.

On the question of whether some such scheme as that sketched in the Paper would actually make over-cloud flying a commercial proposition agreement was not so definite. It was clear from the remarks of most of the pilots of recent experience who contributed to the discussion that they were very impressed with the dangers involved *under present conditions* of organisation and equipment, and stress was laid upon the inadequacy of meteorological forecasts of local fog in this connection. A body of opinion such as this coming from pilots of known reputation and experience deserves the most careful consideration, but I venture to suggest that most of the remarks that were made on this subject were made on the tacit assumption that organisation and equipment would remain much as they are to-day. I am myself in agreement, as stated in the Paper, that forecasted estimates of fog received before starting will not be good enough for the safety required in commercial work; that is, in fact, the basis of my argument in favour of the control stations and the wireless telephone. Given, however, that the pilot is informed during his flight of the momentary condition of the under surface of the clouds in front of him, beneath him and behind him, I think that the danger (although not, perhaps, the inconvenience) of fog ought to be practically eliminated.

Again, the present-day pilot has still to find his aerodrome when he comes down; this makes it very difficult for him when the clouds are below 500 feet, because then he has to fly blindly about the country looking for his aerodrome, and, as everyone knows, this is not pleasant with low clouds. Suppose, however, that he has continually during his descent, and after emerging beneath the clouds, a comforting voice in his ear telling him on what bearing to steer, he will surely be much less bothered by the fact that the clouds are low and will be able to make his aerodrome in comfort whenever the clouds are high enough for him to avoid buildings, tall trees and the like. Such assistance might well be supplied by an operator on the aerodrome equipped with a wireless directional receiver and a telephone transmitter.

Turning now to the particular points raised by the individual speakers:—

Colonel Beatty said that it is too cold to go high enough to clear clouds unless the tops are comparatively low. Is it not possible to heat the passenger compartments adequately? There must be plenty of heat to spare on an aeroplane if it is rightly used. The speaker cited the glare as detracting from the beauty of overcloud scenery. Cannot this be overcome by the use of tinted goggles or tinted windows to passenger compartments?

Capt. Carter.—Most of these questions have been dealt with in my general answer. The difficulty he experienced with the Gyro Turn Indicator has been explained by Major Dobson and Colonel Bourdillon. I have tried it myself in the air when properly adjusted and found it excellent. I am glad that the discussion has been instrumental in clearing-up this point, as such misunderstandings are apt to retard progress considerably.

Lieut.-Colonel Bourdillon.—I am glad that Colonel Bourdillon agrees with me as to the value of the Gyro Turn Indicator; an opinion from such an experienced cloud flyer is of great value. I disagree, however, with the form of this speaker's remark that the solution of the bad weather difficulty lies *rather* with the possibility of dispersing fog. I would put it " lies *also* in the

possibility of dispersing fog." We are, in my opinion, unlikely to be able to disperse fog in the near future, except over small areas, and this leaves the problem of reaching the aerodrome, and the clear area, untouched; nor does it touch the problem of the forced landing en route. I therefore think that one might say that first there must be developed a general organisation with the same object as the scheme indicated in the Paper, but not necessarily using the same methods, and then fog dispersal (if it comes) will extend the number of days on which such an organisation could be used.

Major Dobson.—It was to meet the difficulty of the clouds coming to the ground locally between control stations that I suggested the possible existence of intermediate observation stations reporting by ground telephone to the main control station.

Major Tomlinson referred to the fact that a single wireless bearing was not so good as two bearings. I agree, when using bearing from fixed stations not on the route and at a great distance, but in the case considered, with stations at relatively frequent intervals *along the route*, one bearing used as I have indicated should surely be sufficient. The language difficulty raised by him is a serious one, but no doubt it can be overcome. The speaker's remarks as to the expense not being warranted at present may be true, but it is not the better way of looking at the matter that safe methods of travel must be organised first, and the paying traffic will then follow.

Major-General Brooke-Popham.—I agree that the fewer things the pilot has to watch the better, or rather the fewer things the pilot has to think of the better. My experience of the turn indicators, however, is that by the addition of one instrument an enormous simplification is obtained in the mental processes of cloud flying. Stability is undoubtedly advantageous in a cloud, but it does not get over the difficulty of the slowly increasing turn, nor do I believe it to be practicable to leave the aeroplane to look after itself in a bumpy cloud; clouds are so very bumpy inside.

Capt. Douglas considers that passing up through several thousand feet of clouds is practicable without special instruments. It is certainly possible, but in my opinion it is not a commercial proposition with average pilots. I agree with him that by flying high difficulties of local fog that might otherwise be very serious may be avoided altogether.

Commander Warrington Morris.—So far from believing that sextants should be thrown overboard, I am a great believer in their future for aerial work, but for long voyages, possibly over sea or for long flights off the beaten track; not for the type of flying under consideration, along much-frequented routes in relatively short stages.

Major Heckstall Smith.—I was particularly pleased to hear this speaker—one of the heads, I believe, of a large commercial organisation—emphasising the necessity of spending money on research. Naturally we who try to do research think so, but then we may be biased.

Mr. J. R. Pannel.—I cannot say what advances have been made in the direction of removing hysteresis from aneroids. During the war I had to carry out tests on a special type of aneroid designed to avoid "lag," and I found it remarkably accurate. The aneroid was, I believe, designed by Major Holt and was reported upon to the Technical Department of the Air Ministry in Orfordness Report A/5. Whether it would be of any value for this purpose I am unable to say, as I cannot remember the details of its construction. It might be possible to know one's height above the ground fairly accurately by carrying an aneroid synchronised with the aerodrome aneroid and by being given the reading of the latter on the telephone just before landing.

General Sir Sefton Brancker.—I very much appreciate General Brancker's remarks about the experimental side of the R.A.F. and the old R.F.C. I take it to apply principally to those who were killed in the course of their duty; undoubtedly accidents had an uncanny way of picking out the very best of the experimental staffs, and I was glad to hear his public tribute to their memory, for since the best men among us have been killed it is to the dead rather than to the living that such a tribute applies. General Brancker's speech was, I think, most encouraging, showing as it did an implicit belief in the future of aeronautics in spite of his unrivalled knowledge of the detail difficulties of the present time. I think I can explain to him why, being (to use his own words) "a pretty bad pilot," he still does not find such serious difficulty in flying in clouds. It is because, as he says, he flies mainly by instruments—a bad habit out of clouds, but an essential habit within them. I can say this with a clear conscience, because exactly the same applies to myself.

The question raised by the speaker of mountain ranges intervening was one that I had not considered; obviously it provides another strong argument in favour of over-cloud flying, for on many days one would not be able to cross mountain ranges without flying in or over clouds; here, then, there is no alternative, it is a case of flying over clouds or not at all on many days.

Possibly there is a good deal in the General's remarks about pilots all speaking at once, but there are also objections to the alternative lighthouse systems that avoid this difficulty, for by the latter systems the pilot requires directional wireless *on the aeroplane* in addition to the telephone and, above all, requires to know how to use this wireless. I am, of course, quite unable to make any dogmatic assertion as to which system will prove the best in the long run; I imagine both would have a trial once the control stations were laid down and the wireless apparatus installed.

With the *Chairman's* remarks I am in complete agreement, especially with regard to the reliability of engines, by far the most important problem before aeronautics at the present time. Given absolutely reliable engines, these other problems such as we have discussed to-night yield comparatively easily; failing reliable engines, they become practically insoluble. I wish to join with him in his appreciation of the aircraft firms and pilots who have kept the London—Paris service going through the winter. All the scientific research in the world taken ten times over would produce little result were it not for people like these, who push along with the actual practical application of the subject on a commercial basis in the face of appalling difficulties and no little danger.

CONCLUSIONS TO BE DRAWN FROM THE DISCUSSION.

My main object in writing this Paper was to provoke a discussion amongst responsible people from which some conclusions might be drawn as to the desirability and practicability of flying over clouds as a routine in commercial work. Taking into account the positions held by the speakers and their reputations in the world of aeronautics, this object may be said to have been achieved.

I think that the following conclusions may be taken to summarise the general trend of opinion in the discussion:—

1. That the power to fly in safety over clouds would be of great value to the commercial application of aviation.
2. That routine flying over clouds cannot be undertaken safely with the facilities at present available to the commercial world.
3. That probably it could be made safe with a suitable organisation of ground stations and meteorology and provided that reliable instruments were more generally available. Agreement was not, however, so general as to exactly what organisation and instruments are required.

If these three conclusions drawn from the discussion are correct, then it is of the greatest importance that the development of the necessary apparatus, etc., should proceed as rapidly as possible; in particular, the development of methods of obtaining continuous records of the conditions above clouds. One gathers from Major Dobson's remarks that the kite balloon instrument for giving such a continuous record, without pulling the balloon down except for re-inflation, is proceeding slowly because "the possibility of getting any such instrument into actual use is apparently remote at present." Some such instrument, or its equivalent is, however, one of the fundamental requirements of routine flying over clouds, and, if the above conclusions are correct, its development becomes a matter of great importance to our ultimate commercial success in the air.

Whatever may be the final outcome, whether over-cloud flying will prove to be impracticable—which I do not believe—or whether the methods do, or do not, bear any resemblance to the imaginary systems sketched in my Paper, I think it is clear that we cannot, as a nation, afford to ignore the possibilities that may be latent in over-cloud flying, and that, therefore, the experimental development both of organisation and instruments for this purpose is a matter that we are bound to consider seriously whether there is any immediate gain apparent or not.

The CHAIRMAN, in proposing a vote of thanks to the Lecturer, said there was still a good deal of discussion about pilots believing or not believing in instruments. Every pilot flew by one instrument at least, and that instrument was the earth, in which a pilot had so much confidence that he knew it was always right. When he went into the clouds and lost the earth he had not sufficient confidence in the other instruments, and often went by his own private feelings; if he followed the same plan with regard to the earth, he would come to the same kind of grief that he came to when he did not rely on his instruments. It was not entirely his own fault. Instruments were still capable of a good deal of improvement, and the necessary education would follow naturally on the improvement. As it was there had been an extraordinary increase during the war in the efficiency of pilots.

There were problems in regard to directional wireless telegraphy which had not yet been solved, and which were very important for the future of aerial navigation. If commercial aeronautics was going to succeed, it must do so by night as well as by day. There were indeed many advantages in flying at night; the flying weather was often better than in daytime. But directional wireless was liable to big errors at night; errors up to 20° or 30°. A wireless directional station operating on the Mediterranean occasionally gave the position of known stations as much as 90° out. This might have been due to the peculiar local conditions, but until the causes of such errors were thoroughly understood navigation by directional wireless must be regarded with a certain amount of suspicion.

The most interesting contributions to the discussion came from people who had been engaged practically in the extraordinary achievements during the last few months of the Aircraft Manufacturing Company. Capt. Carter had asked whether when an engine failure occurred, it was preferable to be above the clouds, or below the clouds and 300 feet from the ground. If one engine of a twin-engined machine failed at a height of 300 feet, the pilot would be likely to be landed in serious difficulties at once, and might not have time to right the machine and get it under control before he hit the earth. This was also likely to happen with single-engined machines, with all but the very expert pilots. He would rather be high up—and he thought most practised pilots would—in order to have plenty of room to get complete control of the machine. With proper instruments one need not "spin through the clouds," and could come through

the bottom of it pointing up-wind in the right attitude. The fact that one could not see a suitable landing place a few seconds beforehand was not a very serious difficulty. Good flying in bad weather was still largely a question of psychology.

It seemed to him the improvement of the reliability of engines was by far the greatest problem before us at present. With an engine as reliable as the marine engine, cloud flying would become easy. Without a reliable engine it was hard to navigate either over or under clouds in bad weather with the degree of accuracy and confidence which would make it pay in commercial aeronautics. Designers had no very great inducement now to design aircraft engines, because it paid them better to design motor-car engines. Extreme performance was more important than extreme reliability during the war, but extreme reliability was of far greater importance now.

It was clear that in many directions there was still urgent need for further research on the problem of aerial navigation. Fortunately, in Prof. Jones Cambridge University had a man who was not only by his scientific qualifications eminently fitted for the Chair of Aeronautics, but who had also a most complete, all-round, practical knowledge of the aeroplane and of its behaviour in the air.

He hoped he would find an opportunity to go on with the type of work of which he had given so interesting an account that evening.

PROCEEDINGS.

TENTH MEETING, 55th SESSION.

The Tenth Meeting of the Fifty-Fifth Session took place in the Hall of the Royal Society of Arts, London, on Wednesday, March 17th, 1920, Colonel the Master of Sempill presiding.

The CHAIRMAN, in introducing the Lecturer, Major C. F. Abell, O.B.E., said he was well fitted to give his views on the future requirements of airships as regards engines, whilst, at the same time, giving a general summary of the work done by airships during the war. He was an Associate Fellow of that Society and belonged to other engineering societies, and he had a very wide experience before joining the Royal Naval Air Service at the beginning of the war as an engineer officer. He was first of all with Messrs. J. and H. McLaren and latterly with Messrs. Maudslay's and Messrs. Wolseley's. Since leaving the Air Force he had joined the editorial staff of the "Automobile Engineer." He had been responsible at Kingsnorth for the "type trials" of all engines used in airships, and also the design of power units and other kindred parts. He had also originated the starting and running of engines on hydrogen. Hydrogen starting was used with success at the front for the first time during the winter of 1917. Claims had recently been made abroad in this connection, but there was no doubt that the Lecturer was the originator of the idea, and all credit should be given to him.

Major ABELL then read the following Lecture :—

AIRSHIP MACHINERY, PAST EXPERIENCE AND FUTURE REQUIREMENTS.

Past Experience and Future Requirements.

The object of this Paper is to set out in simple form a description of the various types of machinery used during the war in airships, so that the very wide experience gained in the three million miles flown, largely no doubt in small ships, may be of some value to those interested in the design of ships of more ambitious lines.

In the remarks on the various engines in the Paper it is not intended to criticise in any way the particular engines as aero engines, since it is realised that in practically all cases the engines discussed were designed for aeroplane propulsion, and for that purpose were no doubt all that could be expected or desired.

Any critical points raised regarding their design or performance only show that the requirements in aeroplanes and airships differ vastly.

It is proposed first to describe the engines and installation work which were used in the various ships built during the war, and as a result of the experience gained from them a few requirements in the design of an engine and in the general layout of the installation will be mentioned.

S.S. Ship.

This type was the first built by the Service during the war, which carried out successful patrol work. They were fitted with an 8-cylinder Vee engine of about 70 horse-power, and were air cooled, and the standard B.E.2.C. fuselage was used, with the addition of an extra petrol tank secured under it, so that longer

patrols could be carried out. A few cases of patrols of over 12 hours' duration are on record.

The following points rendered this type of engine somewhat unsatisfactory :— (1) No starting gear. It was necessary, if the engine stopped during flight, for one of the crew to climb out on to the landing skid and swing the propeller. This was obviously a dangerous job, and although frequently carried out successfully it was not a desirable feature. (2) Air cooling by means of funnel-shaped cowl. This was found to be a difficulty from the very start, and increasing the size of this cowl to the utmost limit considered practical from the point of view of head resistance did not obtain satisfactory cooling, as the whole trouble was the fact that the speed of the ship was about 30 knots lower than the speed of the aeroplane for which the engine and cowl was designed. However, pilots soon got to know that their engines would stand up well if they ran them at reduced speed, and therefore patrolling was carried out at about 1,400 revs. Whenever a ship was caught out in a breeze of wind so that the pilot had to run his engine all out to get home, the engineer officer had a job of work to do after the ship landed.

A third point which required a good deal of attention was the carburation of these engines. As an aeroplane must have maximum revs. and as these ships were so slow that proper cooling was impossible at maximum revs. the carburettors had almost invariably to be faked to give satisfactory running at low and intermediate speeds, since it is obviously a difficult proceeding to land an airship with an engine running very unsteadily. It was, therefore, found necessary to adjust most carefully the carburettors, and in some cases to alter the induction pipes, before an engine was considered to be good enough to be put in a ship.

As regards the installation generally, both the petrol and oil systems of this type of ship left something to be desired. For instance, it was almost impossible to gauge the quantity of fuel on board after a few hours' patrol, the pilot having to rely on a table of fuel consumption at various revs. given to him by the engineer officer, and the amount of fuel on board at the start, working out his fuel consumption as he went along. It is easy to see that with this method a carburettor flooding or a slight crack developing in a petrol pipe during flight would throw all calculations hopelessly adrift. The petrol gauge fitted on the gravity tank was, of course, of some use, but having to be fitted some distance astern of the gravity tank itself, its readings were of course fluctuating as the ship pitched about.

The oil system, too, was unsatisfactory for long flights. A certain quantity, about three gallons, was carried in the base, and a further supply in a small tank which was fitted with two or three cocks at various levels. The pilot turned on these cocks, starting at the top one, after so many hours patrol had been done, and hoped for the best, the only tell-tale being a small oil pressure gauge on the dash.

In spite of these things, however, thousands of hours of satisfactory patrol work were accomplished, and the ships were considered a success as far as they went.

Coastal Ship.

This ship was designed to give longer patrols at higher speed than the S.S. type, and was fitted with two 150 h.p. engines, one as tractor and one as pusher. The engines were 8-cylinder Vee, each row of four cylinders being cast in one block and water cooled, and the propellers were geared down two to one, the normal revs. of the engine being about 2,000.

As in the case of the S.S. ship these engines were designed for aeroplane work.

The following are a few points which may be mentioned :—

(1) Compressed air starting gear. This system, of course, relies for its

operation on the supply of highly compressed air in very heavy receptacles, and, therefore, the number of starts available is limited, which is unsatisfactory for long patrol work.

If everything were in good condition the air starter worked quite well, but given any small defect, such as a few slightly warped exhaust valves, so that when cold, compression was bad, and on turning on the air the engine turned over slowly and the air expanding on its journey through the engine, lowered the temperature of everything it came into contact with, making subsequent attempts more and more difficult. This is a point which in the days of war spirit was a very important one.

Another point was the presence of moisture in the compressed air. In cases where a fair number of attempts to start had not been successful, examination of plugs showed considerable dampness. This, of course, may have been due to a bad compressor, or to bad handling of the compressor in the workshops, whereby the water separator was not being attended to when bottles were charged, but it is easy to see what serious consequences a thing like this might have in a ship far out to sea.

A further point is the air non-return valves in the engine cylinders. While running, the smallest leak in any one of these would, if not found out in time, melt away the union brazed on the air supply pipe, so that further starts, if required, would be impossible.

A feature which rendered engines of this type unsuitable was the fact that they were geared engines without flywheel. Owing to the fact that at times the engine had to be run at a speed at which the crankshaft period came into action, the method of securing the gear wheels on their shafts either keys or splines suffered considerably. A flywheel geared engine would not have suffered in this respect to such a great extent. For aeroplane work, for which this type was designed, the crankshaft period came at a speed which was very seldom required as it was too low for flying and too high for landing, but for airships it was necessary occasionally to run at this speed, with unfortunate results.

Another type of engine was also used as a pusher in the coastal ship, this being a 12-cylinder Vee engine of about 240 horse-power. These engines gave quite good results as they were fitted with handle starting, which was easy to operate, and they were good as regards flexibility. The exhaust arrangements, however, were always a source of a little anxiety, as the exhaust ports were inside the Vee, and it was, therefore, difficult to get a clean run of pipes overboard. There was also danger from a blown exhaust port joint causing fire as the envelope was very low down to the car in these ships.

In a few of these engines also the magnetos were fitted in the Vee between the cylinders and it will be easily imagined the amount of work entailed in getting at any of the magnetos to adjust and clean. There is one point, however, which in these engines gave a certain amount of trouble, and this was the lubrication of the overhead camshafts and rockers. There was an oil pipe lead to these shafts from the main system, but the cams and rollers, etc., relied chiefly for their lubrication on the oil vapour which was generated in the crankcases and allowed to find its way to the atmosphere via large aluminium pipes connecting the camboxes with the crankcases. As the amount of oil vapour generated depends largely on warm pistons, and as these engines were run for the greater part of the time at something less than full speed, which is usual practice in airships, the oil vapour supply was reduced. At any rate trouble was experienced with scored cams and seized rollers, a trouble seldom occurring with this type of engine in aeroplanes. This is merely given as an instance of the difference between airship and aeroplane engine requirements.

The petrol system in the coastal ships was a simple arrangement of two steel pressure petrol tanks, one near each engine, supplying the carburettors direct.

Pressure was maintained by small windmill air pumps, with a hand emergency pump. Under ordinary circumstances the windmill pumps were satisfactory. The petrol tanks were connected together so that the forward engine could be run off the aft tank and vice versa. Large diameter screw-down ballasting valves were fitted to each tank so that the petrol could be discharged overboard quickly in case of emergency.

The oil system in these ships requires no description, consisting of merely a tank and a few pipes.

North Sea.

The engines in these ships were 12-cylinder Vee engines of 240 horse-power, with overhead camshafts and valves, the power being transmitted through a reduction gear and a shaft with universal joints to the propeller. This shaft, which was about eight feet long, was eventually discarded, as it was found to be responsible for setting up periods of resonance in the engine, causing failure of various parts. Two ships of this class were, therefore, altered and the propellers fitted on the engine itself, as in aeroplanes, and the ships thenceforward ran without trouble, several very good patrols being carried out, one of the best being a continuous run of 22 hours, an air speed of over 45 knots being maintained all the time.

The radiators in these altered ships were fitted between the engine and the propellers, which were, of course, pushers. By this means satisfactory cooling was obtained even while the ship was stationary, and it was possible to run the engines full speed on the ground without boiling.

The petrol system in the N.S. ship is perhaps worthy of mention. These ships carried twelve cylindrical aluminium tanks holding about 90 gallons each. These tanks were slung from the internal rigging of the ship, and were situated in the envelope, inside fabric sleeves. Brass cocks of $\frac{3}{4}$in. bore were fitted to each tank, and these were controlled by wires from the engineer's cabin. All the tanks were coupled up to petrol mains of 1in. bore secured to the bottom of the envelope, and provided with several expansion joints in the shape of rubber flexible hose. The tanks were arranged in groups of three, each group having its own petrol main coupled up to a service tank fitted above the engineer's cabin. This service tank was fitted with a gauge calibrated in gallons, so that the engineer could watch his fuel consumption and report to the captain of the ship. Refuelling was carried out as follows:—Long flexible hoses were coupled up to special fittings provided in the petrol mains on the envelope, and the master cocks provided on the service tank for shutting off the mains therefrom were closed. Petrol was then pumped by semi-rotary pumps from the shed petrol casks, up the flexible hoses into each tank as required.

No gauges were fitted to the main petrol tanks, the pumping being continued until petrol ran from the overflow pipe.

The oil supply system in these ships was as follows:—A cylindrical tank about 10in. diameter, holding about 24 gallons, was secured horizontally alongside each engine, and there was a baffle plate fitted across the forward end of the tank. This forward portion only was used as the circulating tank, and held about 10 or 12 gallons, and was fitted with a sounding rod as a gauge. The engine ran on the oil in this compartment, and when it was required to add fresh oil thereto, it was necessary to open up a cock in the pipe leading from the aft end of this tank to the pump, and close the cock in the main suction pipe. By this means fresh clean oil was forced direct into the engine from the reserve, returning in the ordinary way to the circulating tank.

The sounding rod was found to be very difficult to read in flight as the wind blew away the oil level mark as soon as the rod was withdrawn from the tank.

These engines were fitted with hand starting gear and an accumulator ignition, which made starting up a very simple process.

Later ships of this class were fitted with engines of a different type, having six vertical cylinders, overhead camshaft and valves. These engines gave about 280 h.p. at 1,450 revs. and weighed 900lbs. complete.

Generally speaking, this type of engine gave good service, but a few points are considered to be worth mentioning.

Carburation.—The induction pipes were of such design that proper distribution of mixture was only obtained at full speed, and it was found on test that two cylinders out of the six invariably showed signs of weakness at a cruising speed of about 1,200 revs. The result of this was, of course, burnt exhaust valves, and these required frequent attention. This is another instance of an aeroplane engine failing to fulfil airship requirements.

The carburettors were very erratic in their working, the mixture varying from extremely rich at slow speed, to very weak at about $\frac{3}{4}$ speed. They were also very liable to catch fire if, owing to a sticky throttle control, the throttles were opened up suddenly. The maintenance of this type of engine in sound condition was, however, a simple matter, as they were of a simple design and of sound construction, and of very little complication. On one occasion in a ship of this type, while patrolling over the North Sea the engineer had occasion to stop one engine, to replace a valve spring which he had noticed was broken. In attempting to fit a new spring he clumsily allowed the valve to fall into the cylinder, while the piston was at the bottom of its stroke, so that the valve fell right in, clear of its guide. However, he set to work to remove induction pipe, exhaust manifold, overhead camshaft, etc., took off the cylinder, replaced the valve and a new spring, and was running again in something under five hours. This was a very good piece of work under the circumstances, and, although the greater part of it would have been avoided except for a little clumsiness at the start, it illustrates the extent to which engines can be overhauled and repaired during flight in airships, provided their design will allow of it.

The petrol system in the later class of North Sea ship was in the main features the same as in the earlier class, which have been described.

The oil system, however, differed somewhat. It was arranged as follows :—

A circulating oil tank holding about six gallons was fitted alongside each engine, well above the suction pump, so that the latter was always flooded, and the engine ran on this oil, the engineer watching a glass tube gauge fitted to the side of the tank. On requiring to replenish the oil in this tank, the engineer had to step on to the starting platform just ahead of the engine and pump (by means of a small semi-rotary pump) new oil from a large storage tank fitted in the bows of the power unit. This system entailed a certain amount of work on the part of the engineer, but it was considered desirable to make the engineer get out of his cabin occasionally alongside his engines so that small defects could be noticed before they developed into big ones. It was not thought to be good practice in airships to fit machinery which is too automatic in its action, since if it is working well the engineers in charge lose interest through having nothing to do, and fail to notice small defects in time.

S.S. Zero.

These were small ships fitted with a single 75 horse-power engine with six vertical cylinders, overhead camshaft and valves. Handle starting as in motor car practice was provided, which, in conjunction with the accumulator ignition fitted in addition to magneto, restarting in the air was a very simple proceeding.

This type of engine gave remarkably little trouble, and as a class these ships

were very successful. Having only one engine, the fact that the overhead camshaft rendered cylinders and valves, etc., somewhat inaccessible, does not appear to be of such importance as in the case of ships with several engines.

The petrol in these ships was carried in aluminium tanks hung on the sides of the envelope in fabric slings. As the head of petrol above the carburettors was about 24 feet, special arrangements had to be made in the float chamber to counteract this, and the simple method of reducing the area of the needle valve seating was adopted. No petrol gauges were fitted, the tanks being practically out of sight of the crew.

The oil system was as in the early coastal type, merely a tank and two pipes.

S.S. Twin.

The first S.S. Twin was practically a Zero with two engines fitted on a wooden framework at the aft end of the car, and driving pusher screws, engines being of the same type as those used in the Zero ship.

A later S.S. Twin was fitted with two 6-cylinder 100 h.p. engines having all cylinders cast together in aluminium and with overhead valves and camshaft. It is regretted that no information as to the behaviour of this type of engine in the Service is available, but it would appear to belong to a type not as sufficiently accessible for repair and overhaul as could be desired.

Rigid Ships—R.9.

This ship was the first rigid to be built during the war. She was fitted with four 180 h.p. Maybach type engines built in this country, and they drove swivelling propellers through gearing. The cars were arranged, one forward and one aft, each car having a pair of engines and propellers.

At a later stage the machinery installation was altered and in place of the pair of engines fitted in the aft car, the power unit, consisting of engine, gearbox, etc., taken from the wreck of L.33 at Little Wigborough, was fitted. This German engine was designed with a compression ratio rather too high for the low altitude work for which R.9 was intended, and this was accordingly lowered by fitting a new set of pistons.

This engine was of course a 6-cylinder vertical, in which simplicity and accessibility were the main features, and airship engineers who had actual flying experience with this unit universally praise it for its reliability, flexibility, etc.

Experience of this set was also gained in engine trials on the dynamometer at Kingsnorth, which showed that it was an engine remarkable in many ways for the ease with which it could be stripped for overhaul, the facilities provided for adjustment of oil and petrol services, etc. As an example of accessibility a cylinder was removed and replaced, and the engine running on load again in under two hours.

The Maybach system of suction pump starter was used and was found quite satisfactory.

The petrol system in this ship was as follows. Tanks were carried in the keel and over each gondola was a group of tanks which might be called service tanks. Petrol was pumped from other tanks along the keel to these groups of service tanks by means of small semi-rotary hand pumps, which were also used for trimming the fuel in the ship as occasion arose. The petrol fell by gravity from the groups of service tanks to a float controlled sump in the bottom of the gondolas, whence it was pumped by the petrol pumps incorporated in the engine design to the Maybach floatless carburettors.

The oil system was a simple straightforward job. Oil drained from the engine crankchambers by gravity to a tank situated immediately underneath, and

was circulated by a plunger oil pump through filters to the engine bearings. An oil cooling radiator could be put in the circuit as required. Hand pumps of plunger type were supplied for draining the oil tank of any water, and for priming the engine system before starting up.

Radiator was fitted forward of the gondola and the temperature was regulated by means of a blind.

R.23 Class.

In this class of ship were fitted three gondolas, the forward and after cars being of the same design, having each a 12-cylinder 300 h.p. Vee engine driving a pair of swivelling propellers. The amidships car contained a pair of similar engines set athwartships, each driving one fixed propeller through bevel gears.

The engines were fitted with 12 independent cylinders and overhead camshafts and valves, and were provided with hand starting gear.

The exhaust manifolds of these ships, which were, of course, water cooled, gave a certain amount of trouble due to their becoming porous after a short period of service. They were of sheet steel, welded up.

R.23 X.

This class was similar in a great many respects to the R.23 Class, except that an internal keel was fitted instead of an external one. Machinery was as fitted in 23 X. Class. R.29, however, was altered, and in place of the double engined 'midship car, a single 300 h.p. Vee engine was fitted, and the propeller was driven through a reduction gear fitted in the stern of the gondola.

The petrol system in 23X. Class was somewhat different from that of 23 Class, the tanks being fitted in the hull of the ship alongside the keel, and not in it.

A large diameter aluminium pipe was fitted underneath the tanks, to allow petrol to be discharged overboard at a high speed when necessary. This pipe was also made use of in refuelling the ship in the shed, and it was found that considerable time was saved by this method, against the previous method of using the small diameter running down main.

R.31 and 32.

These two ships were built of wood, and were fitted with five 300 h.p. engines. All the gondolas contained a 12-cylinder Vee engine, which drove its propeller through a reduction gear fitted at the extreme stern. The two amidship gondolas were fitted with reverse gear. Electric starting motors were fitted with hand emergency gear, and the dynamo for charging the batteries was driven by "Vee" belt from the transmission shaft between engine and gear box.

Radiators were fitted forward of gondolas and temperature was controlled by means of a blind.

The oil system consisted of a circulating tank in the gondola, the oil circulating from this to the engine, and being returned by the pump either through an oil radiator or direct to the tank as was required.

The reserve oil tank was carried in the hull of the ship, and ran by gravity into the circulating tank.

Petrol tanks were slung alongside the keel, and were arranged as follows:— In the keel adjacent to the gondolas were fitted groups of tanks, each group being of three or four tanks, and these were regarded as service tanks, and fuel fell to the engines by gravity. The centre group of tanks was fitted with an air pressure system, as these gondolas were slightly above the level of the keel when the ship was on even keel.

All other tanks, other than those in the groups, were arranged so that they

could be slipped overboard in case of need, and, therefore, were not permanently coupled up to the system of piping. Flexible connections were carried and used as required in conjunction with small semi-rotary pumps. Thus in cases where the ship got badly out of trim for any reason, it became necessary to move perhaps several tons of fuel from one end of the ship to the other by means of a small pump.

Refuelling was carried out by forcing petrol by hand pumps from the shed carts into special fittings provided on the running down main into the tanks, and owing to the small diameter of the main this occupied a long time, and was very arduous work on the pumping party.

R.33 and 34.

These two ships are perhaps too well known to need a long description here. They were fitted with five 275 h.p. 12-cylinder Vee engines, arranged as follows :— One forward, on centre line. One on each beam driving a propeller, through a reversing gear box, and two in the after car, geared together, to drive one propeller.

Electric starting motors with hand emergency gear were fitted.

Petrol was carried in the keel in cylindrical aluminium tanks holding about 65 gallons each. These were arranged in groups, four forward, three port amidships, three starboard amidships, and six aft, all of which were fixed. The remainder, 70 in number, were slipping tanks arranged so that they could be dropped overboard if required.

Fuel was trimmed from the slip tanks to the fixed tanks by semi-rotary pumps which were used also for trimming the ship if necessary.

Petrol flowed by gravity from the fixed tanks to the cars, each of which had a float controlled tank fitted in the roof, from which the engine was fed.

The oil system consists of a small circulating tank, holding two or three gallons which fed the engine, and the hot oil returning was passed through a radiator or direct to the tank as required. The main storage tank was fitted in the keel. The radiators were fitted about amidships in the cars, and the temperature was controlled by a blind in all cases, except the aft car, in which case the radiator was arranged to hoist up and down inside the gondola, flexible rubber armoured hose being used for the connections. Electric water heaters were fitted in the systems for shed use.

The power was transmitted from the engine through a Hele Shaw clutch to a spur reduction gear box fitted aft. A dog clutch was provided between the clutch and gear box so that when warming up engines before flight it was not necessary to run with the Hele Shaw clutch in the out position.

The wing cars only were provided with reversing gear boxes. In the after cars, two engines were coupled up to the same propeller through a plain spur gear box, without reversing gear.

The following are a few of the requirements in engines and installations as they appear to the airship engineer, the point which it is desired to emphasise being that airships have peculiarities all their own, and that engines or minor details which are perfectly satisfactory for other services are not necessarily suitable for this class of work.

The Engine.

This should be a single line engine of six cylinders, the reasons for this demand for a single row of cylinders, being that an engine of this type gives a greater degree of accessibility ; that the exhaust piping arrangement is simplified ; and that the space available in a gondola of a certain size is more with this type than with a " Vee " engine.

Cylinders.—These should be made separately and should all be interchangeable. In case of a collapsed piston and cylinder badly scored, the engine with separate cylinders can obviously be overhauled in less time than one having cylinders cast in pairs. There should be no water pipes connecting the cylinders, as these interfere with their removal.

Valves.—These should be fitted in the head of the cylinder and operated by overhead rockers, which in turn are operated by push rods from the camshafts. With this construction the timing is not interfered with when cylinders are removed.

Crankcase—Top Half—should be fitted with inspection doors at each side, so that big ends can be rebedded without much difficulty. If possible inspection doors should be fitted big enough to allow pistons and connecting rods complete to be removed without disturbing the cylinders, but in cases where the cylinders are made easy to detach, there is less need for such large inspection doors. They should be big enough, however to allow big ends to be refitted from the side, as distinct from the top of the crankcase. The camshafts should be fitted in the top half of the crankcase, one on each side of the engine, and the design of the case should be such that the crankshaft journals are supported in this half with bearing caps, and not in the lower half of the crankcase as in some engines. Cylinders should be secured by readily accessible bolts. Special spanners should not be required. There should be no oil ducts cast in the crankcase. The main oil lead should be bolted to the outside where it can be seen. The oil ducts supplying the main bearings should each be fitted with a gauze filter easily detachable.

The lower half should carry the oil pumps in an easily accessible position, but otherwise should be more or less an oil splasher.

Magnetos should be driven from any convenient point, preferably from the camshafts. They should all be arranged to rotate in the same direction, to simplify the carrying of spares in the ship. There should be two magnetos per engine. A flexible coupling should be fitted, provided with a method of quick adjustment of the timing.

Lubrication System should be of the "dry base" variety. There should be two pumps for draining the base and one supply pump. The scavenging pumps should be fitted one at each end of the oil base chamber, so as to give efficient drainage when the ship is at a steep angle. The supply pump should also be fitted in the base and could be driven by the same gear as the other pumps, but must be readily accessible.

All crankshaft and connecting rod bearings should be oiled under pressure.

Water Pump should be centrifugal, and so fitted that it can be instantly replaced if necessary. The packing gland should be arranged, of course, on the suction side and so that it can be repacked with engine running if required; it should not be possible for any leakage from this gland to find its way into the engine interior.

Carburettors and Induction Pipes.—Carburettors should be fitted in a high position on the engine so as to interfere as little as possible with the access to inspection doors. Induction pipes should be fitted with efficient flame baffles. All carburettor controls should be integral with the engine. Carburettor drains and overflows should be carried overboard well aft.

Safety Devices should be employed whereby either lack of oil pressure or excessive speed would stop the engine at once by cutting off the fuel supply at the jet. It is important that this control should operate on the fuel and not on the ignition, as when an engine which is working under heavy load is switched off it carries on self-igniting and eventually comes to rest after running astern violently for a few revs. The effect of this on the transmission might be very

serious, and in addition the running astern would fill the gondola with exhaust fumes, which might easily gas the mechanic if he happened to have the windows shut.

Starting Gear.—A starting gear of some description will of course be necessary, and this problem becomes one of difficulty when a big bore engine of few cylinders is contemplated. The electric starter, employing a small high-speed motor, run from a battery, driving the engine round very slowly, through a reduction gear might be used, but there is the weight to be considered, which, if the battery is big enough to give sufficient turns to the really refractory engine, will be considerable. Further, the engine should be turned over sufficiently quick to pick up fuel from the jets.

The starting apparatus recommended is the suction pump starter as fitted to the engines in the German airships. This apparatus has many advantages. It is simple and effective, light, requires no external doping, is safe, as it operates by suction, and, therefore, the risk of petrol vapour escaping and settling in the bottom of the gondola is reduced to a minimum, and it does not set a limit to the number of starts. A brief description may be of interest. By very simple mechanical means all the valves in the engine are lifted together about 3/32in. from their seatings, and simultaneously the exhaust pipe is closed to the atmosphere and opened up to a large diameter hand-operated suction pump, the working of which draws air and petrol from the carburettors into all cylinders. After a few strokes of the pump, the valves are reseated and the engine may be started by hand magneto, the valve in the exhaust pipe having been re-opened to atmosphere.

The exhaust manifold should of course be efficiently cooled. Water cooling has disadvantages as regards weight, and the fact that the radiator has to be increased in size to such an extent to provide the additional cooling required. An air cooled exhaust system might be satisfactorily arranged by providing suitable ribs on the manifold, enclosed in a fairing, and utilising the exhaust outlet from the silencer to create an induced draught.

All exhaust joints should be recessed, and the exhaust washers should fit these recesses accurately, so that a washer blown out is quite impossible. Further, in a suction starting system as described above, it becomes increasingly important to have sound exhaust joints.

As regards future requirements in engines, it is thought that the possibility should be considered of using engines of 500 to, say, 1,000 horse-power, driving propellers at a distance of, say, 50 feet as a maximum. An arrangement such as this would enable the heavy gondolas to be carried in that position on the hull, which the constructional engineers consider to be the best, and the propellers would be driven through shafts at various heights up the side of the hull.

Installation.

The engine seating in the gondola should be arranged to give free access to oil pumps, and to the bolts securing the lower half of crankcase, and there should be sufficient room in the well under the engine to allow the bottom half to be lowered and drawn out from forward. The gear box should be situated well away from the stern of the gondola, so as to be accessible, and to allow the gondola to be streamlined off.

The radiator should be fitted aft, as close to propeller as possible, so that adequate cooling is obtained at the slowest air speeds of the ship. This position will be found to enable the size of the radiator to be reduced considerably.

The transmission shafting should, of course, be well provided with flexible joints, of some very simple form. The spherical splined type is suggested as these are very simple and reliable, and are very noisy if any periods are encountered in the engine or transmission, which noise will tend to prevent an engineer holding on to a period any longer than absolutely necessary.

The reduction gear box should be of plain spur wheel type provided with pump lubrication. Provision should be made for the easy detachment of driving or driven wheels for replacement. In reversing boxes, the oil pump should of course be driven from the driving shaft, so that oil pressure is maintained when going astern.

The propeller brake should be fitted on the tail shaft, so that the propeller is under control even when the gear is in neutral.

The practice of using two engines to drive one propeller through gears is thought not to possess sufficient advantages to justify it.

No doubt the big diameter slow-running propeller which it is possible to use with this arrangement is more efficient, but it is a very debatable point whether the gain in efficiency is worth the extra complication entailed. Further, the running of two engines geared together in this manner is by no means always satisfactory, as it is so difficult to synchronise them, and extended running of them not synchronised leads to vibrations and strains being set up, broken pipes, etc. One engine in each gondola is sufficient, for if two are used, the size of the car at once becomes prohibitive, at least if accessibility to the engines is fully considered.

All filters should be of course in duplicate, so that one may be cleaned while the other is in use.

Valves should be fitted in both suction and outlet water pipes near the engine, so that in case of breakdown the engine may have its cylinders removed without losing a great deal of water.

A petrol flowmeter should be fitted so that the engineer can see at a glance his fuel consumption, and this will help him in stopping loss of petrol overboard if a carburettor float punctures.

All thermometers, pressure gauges, and other instruments should be grouped together on a board fitted to the side of the gondola. As little as possible should be attached to the roof, as this should be easily detachable for the purpose of shifting engines, etc., when required.

Engine.

No suggestion has been made as to the horse-power or R.P.M. required of the engine. Broadly speaking the former should be as high as possible, the latter as low. It is thought that 400 h.p. at 1,400 revs. would be a useful all-round engine.

Of course, the engine speed at 1,400 mentioned above almost definitely calls for a reduction gear if the propeller is to be reasonably efficient, but the sooner the gearbox is discarded the better.

Too much stress cannot be laid on the importance of being able to carry out quite extensive refits in the air. Repairs of the order of fitting a new connecting rod should be possible in say a period of four hours while under way.

Close attention should be given to the design of the engine seatings and gondola generally so that the fitting of a complete new machinery installation is, at the outside, no more than the work of one day. As an instance of this, it was found possible to change an engine in the N.S. class of ship in six hours' work. It is, of course, a far more complicated job to change a set of machinery of a rigid ship, with its gearboxes, etc., but nevertheless it is thought that if universal joints and other details in the transmission and engine and gearbox seatings are of suitable design, it should not be necessary to do any lining up at all.

In the engine design, more importance is thought to attach to fuel economy at all speeds than weight per B.H.P., because of the length of flight the ship may be called upon to carry out, estimated at 100 hours.

The question of recovery of water from the exhaust gases is a most important one, and it is thought that no expense should be spared in the carrying out of experiments on this subject.

It is understood that an engine of large output at a low speed of revolution is now in its experimental stage. In the event of this proving a success, it would appear that the abolition of the reduction gearbox is in sight. Attention should, therefore, be given to the question of a satisfactory form of propeller with swivelling blades. A satisfactory reversible propeller would have further advantages in the ability to adjust the pitch for varying conditions.

With regard to the question of the fuel arrangements, it would appear that the present system, which entails a great deal of manual labour, is not satisfactory, for several reasons. It is slow in operation, both in refuelling the ship, and in trimming during flight, and it definitely calls for extra men in the crew, who could be dispensed with if the system were made more automatic in its action. The suggestion is made that experiments be carried out in connection with propeller drive petrol pumps, several of which could be fitted along the keel on hinged arms so that they could be swung into the ship when not required.

With regard to the type of fuel used, it is thought that the question of paraffin should be thoroughly investigated, since by its use the danger of fire would be reduced to the minimum, and also the question of its cost renders it attractive. It is admitted that the weight of a 500 horse-power engine designed for paraffin would at the present day appear excessive, but for future requirements with, say, a ship of 10 million cu. ft., it might be found practicable to employ machinery much heavier than is at present possible.

I am indebted to the Air Ministry for permission to publish the photographs, and to Messrs. Wolseley, Sunbeam, and Armstrong Whitworth for their co-operation in supplying photographs and detailed information of various airship components.

(These photographs are unavoidably held over.—ED.)

DISCUSSION.

The CHAIRMAN said he was impressed, on hearing this interesting Paper, with the splendid work done by the Airship Service during the war, in view of the difficulties under which the service had operated. They had present at least one of the crew of the R.34, and to these people, as well as to the Lecturer and others like him, a great debt of gratitude was due for making the Service so efficient under such conditions as had been portrayed. What Major Abell put forward was not put forward purely from an academic point of view, but from the point of view of practical men. It was interesting to hear that his engine requirements appeared to be very nearly met by the engine shown on the last slide (the Sunbeam Coatalen "Sikh" 400 h.p.), and no doubt there might be other engines which came up to the standard he laid down. He rather doubted whether gearing could be discarded as easily as the Author thought, and questioned whether it would be advisable to couple the propeller direct to the engine from the point of view of general efficiency of either of the units mentioned. Engine accessibility had to be carefully borne in mind. It would be necessary to compromise. Probably in large airships this would be arranged for in whatever scheme of power transmission was used. It did not of necessity signify that a shaft drive or any form of transmission now commonly known would be used. He would ask Wing Commander Cave-Browne-Cave to open the discussion, and relate what had been and what was being done with regard to the recovery of water from the exhaust, and also the use of paraffin as a fuel, and reversible blade propellers.

Wing Commander CAVE-BROWNE-CAVE said the Author had works, test house and flying experience and considerable weight must therefore be given to the views he expressed. Perhaps the most important lesson he personally had drawn from airship experience was that the great majority of their difficulties might have been avoided if they had had opportunities for carrying out adequate tests on the ground. There was considerable difficulty in reproducing the conditions of aeroplane flight in a test on the ground. The airship conditions could, however, be reproduced with comparatively little expense and with extraordinary accuracy, and a great deal of valuable practical experience could be gained more rapidly than in flight, and expense would be saved. As regarded the defects most pronounced in airship machinery, he suggested in the first place unreliability. If it were possible to make the machinery as reliable as that of a motor car, the anxiety always present in the mind of the officers of the ship would be eliminated. That would go a great way towards making the airship service much more efficient. The unreliability was not as a rule due to serious defects, but to silly little things that went wrong. The only way to foresee those things was by amassing an enormous amount of experience in flying and tests on the ground with the complete machinery units. The next point was fuel economy. The airship had to make longer flights than the aeroplane, which made fuel economy more necessary. He thought 100 hours was the proper basis to take. A 300 h.p. engine weighed, with auxiliaries, about 1,500lbs. and burnt about 150lbs. of petrol per hour, or 15,000lbs. in 100 hours. If an improved engine reduced the consumption from .5lbs. to .48lbs. the saving would be 4 per cent., which would justify an increase of 600lbs. in the weight of the engine. Perhaps the next most important feature was accessibility of parts. Present engine installations could be very greatly improved by reducing the amount of gear that had to be moved when a repair was undertaken. The machinery installation was also the most dangerous part of the ship. If all danger connected with the machinery and the fuel it used could be eliminated it would immensely reduce the risks. The risk of fire was not a serious one, but it was almost entirely due to the machinery. In paraffin or heavy fuel, which was not above its flash point at ordinary temperatures, there would be a great gain in safety. Much could be done by starting the design of the engine car from fundamental first principles. There must be certain necessary auxiliaries for the engine and a certain space for the mechanic. The car should be designed round the engine, and only what appeared essential should be put in. The smallest possible engine car would be secured in that way. The weight and resistance would be reduced and the efficiency of the propeller would be increased. The machinery unit should be designed so that it could be removed and repaired quickly as a complete unit. Even a minor repair might take six or eight hours to make, and if the unit could be taken off as a whole and a new one fitted, there would be a great increase in reliability of working. It could easily be done if provision were made for it. There was the additional advantage in treating the machinery units as standard parts, that they could be developed independent of the progress of the airship, which was necessarily limited by considerations of design. An airship machinery unit should be made as quickly detachable as a railway engine, and should be developed as independently of the remainder of the conveyance. Such an arrangement was possible on an airship, although not so in a steamship. In addition to the engine, the question of propellers wanted considering. Adjustable pitch propellers were a most desirable feature. If one did not want to go at full speed certain engines were wanted at full speed and the others could be stopped. Obviously, if one engine were driving the ship instead of six, the propeller would be badly overloaded, and if there were means of adjusting the pitch of the propeller, much could be done to avoid that loss of efficiency. If the propeller were made with variable pitch a slight extension of the gear would make it possible to reverse the propeller, and that met the Lecturer's idea of avoiding the gear box. A good deal had been done in connection with water recovery, and there was no serious difficulty in getting the heat

out of the exhaust so that the gases were cooled to a temperature below 200deg. F. One trouble was that the cooling surface got fouled by the carbon and oil, and another was that although the moisture was condensed it was difficult to separate the particles of moisture from the gas. There was an obvious desire to employ engines on the Diesel principle. The Diesel engine, instead of burning .5lbs of fuel per h.p. hour, burnt about .38lbs. That was a 25 per cent. improvement, and would justify an increase of 250 per cent. in the weight of the engine. One weighing 12.5lbs. instead of .5lbs. per h.p. would be justified, the Diesel at present weighed 30lbs. or 40lbs. per h.p., so they might have to wait a little time till the weight was decreased and the fuel economy further improved. The use of steam was most attractive for airship purposes, but the consumption of fuel, even at the most optimistic estimate, could not be less than .85lbs. h.p. hour. The use of paraffin presented certain difficulties, but he hoped they would be able to get a paraffin vaporiser which would enable them to use more or less standard engines without making very radical alterations to them. He would like to emphasise the importance of developing the machinery unit as a standard separate item. Such a unit could be developed much more rapidly and cheaply than machinery installed as at present. By adopting such policy the liability to engine failure could be reduced to a minimum, and the safety and reliability of the airships as a whole very greatly increased.

Commander BOOTHBY: They had never had a proper airship engine yet. Most British airships had engines discarded from the aeroplane service, and they were not very suitable. He agreed that they had to go in for economy in fuel. That was the one point to concentrate on. He hoped to hear of experiments in using the Diesel type on one side of the piston, and steam generated by the heat now wasted on the other, on the principle of the Still engine. He thought a rich man could not do a more patriotic act at this time than offer a prize to any designer who would produce a really good engine for airships. One contribution towards fuel economy was the possible use of hydrogen. He thought the experiments had reached a stage which showed that it could be done. Used in conjunction with liquid fuel it would give a gain of 20 per cent. at no extra cost. In two or three years he thought it would be a standard that hydrogen would be used in all airship engines in conjunction with the heaviest fuel obtainable. He was very keen on swivelling propellers. In the Zeppelin type of ship, flying high, one could do without it, but the type of airship coming in the near future for commercial purposes would fly as low as they could, so as to carry maximum cargo, and for flying in bumpy weather something more than the elevators was necessary to keep the ship from hitting the ground in case of emergency, and though ballast could be used for this, once disposed of it was irrecoverable, while an upward thrust from swivelling propeller could be applied again and again. The present design of swivelling propeller was very crude. There were two or three gear boxes between the engine and the propellers. He thought they would get in future a very light type of swivelling propeller, and be able to go ahead.

Mr. CHORLTON (Sir Wm. Beardmore and Co.) said paraffin was only recommended, he thought, because it was less inflammable than petrol. It was a difficult fuel to use, and he hardly thought it would become customary in a normal engine, *i.e.*, as now in service. It could not be used efficiently with an exhaust heated carburettor, because that simply raised the suction temperature, which meant that the compression would have to be reduced, thus causing the power to fall, so that in using such a fuel the advantage gained in one way was lost in another. To be used most efficiently, the paraffin would have to be injected into the cylinders. That had been done with large engines in Diesel practice. Submarine engineers adopted rather a different system to the ordinary Diesel one. Such a system could hardly be used on airship engines because the weight would go up owing to the compression used of 450lbs., as was customary with these engines. He did not think the comparative economies of the two cycles

could be accepted as stated by Commander Cave. The consumption of an ordinary petrol engine might be .5, but the consumption of the Diesel engine with a cylinder of but 8in., possibly as big as any that had been made for aero work, would certainly not be .38. That figure was good for a cylinder of 14in. diameter. He thought for the 8in. cylinder it would be .45. That considerable gain substantially came from having raised the compression. So one might be able to go to an intermediate place, say, a compression of 200, where by injecting the fuel, one got over the risk of pre-ignition, which was otherwise the difficulty when the compression as in present practice was raised. He agreed with previous speakers that it was important that tests of engines should be made on the ground, but unfortunately now there was no money for experiments, and the knowledge obtained from a lot of partly completed ones, would be lost. He believed in doing away with the gear box. Greater reliability could be got by running the engine at a slower speed. It should be possible, on these reduced speeds, to have engines that would run for a week or two without stop. There had been land engines which ran six months and more. The war conditions of an aero engine were entirely different from what would be called for in commercial practice. By easier rating and slower speed, engines would run so well that there was no need to provide them with too many ways of being stripped in the air. In the direct drive, if the speed were reduced to get reliability in the engine, one might begin to lose efficiency in another direction, *i.e.*, the propeller, which now ran faster. One got a reduction in speed of one-third where the efficiency was equal to a large propeller with the gear reduction, but at higher speeds this was not so. Experiments were therefore necessary to obtain efficiencies higher than were obtained at present, for such speed. With the gearless engine should be combined the variable pitch and reversing propeller. The saving in weight by cutting out the gear box and the reversing gear box was equivalent to allowing the engine to run at a slower speed. On the score of accessibility for repair, he had lately been concerned with an engine with loose cylinder heads, which could easily be removed and the valves taken out or the pistons withdrawn. Valves should be prevented from dropping into the cylinder. It was not a difficult thing to do. With regard to the Low or the Still engine, he thought for the sake of simplicity and reliability, they must stick to one type in the engine. The gain in efficiency would hardly justify the addition of all the other parts. If a steam cylinder were added to use waste heat, there would have to be a condenser, and that rather spoilt the power plant as a working proposition for everyday use in the air. It would be of great interest, he thought, if a paper were presented giving the comparative efficiency and possibilities for air work of various systems of internal combustion steam turbine and combined power plant.

Squadron Leader PARRY said out of the very large sum expended on airships during the war, a negligible amount only had been devoted to experiments with a view to the improvement of the engines. To a large extent they had been forced to employ engines which were not required for aeroplanes. It was remarkable that airships had done as much as they had done, when so little attention had been given to what was undoubtedly the weakest part of the ship. But on account of the neglect which had taken place during the war there was all the more opportunity for those who had anything to do with airships and airship machinery to progress in future designs.

Captain J. S. IRVING (Messrs. Sunbeam): I congratulate the Lecturer on a very practical Paper, in fact, the points made were so practical that Major Abell might call himself an "owner driver." Major Abell very rightly made a great point of reliability. Many of the defects which had occurred on airship installations were not peculiar to that particular class of work, but were common to all aviation installations throughout the war, inasmuch that at least 90 per cent. of the breakdowns which occurred could generally have been avoided if great care had been paid to the installation. One might have first class engines, tanks and

controls, but unless these components were connected together in a very careful manner, trouble was bound to ensue and generally did, as many a good run or flight has been spoiled by such trifling things as a failure of a pipe, a filter choked, a water leak or a control cable off its pulley. Up to recent years, the need for greater accessibility of airship engines had not been felt, as in the early years an airship flight of four or five hours was considered rather good. When the sudden call for airships arose, there were no engines available which had been designed for airship work, and the Service had to use, in many cases, engines which had been rejected for heavier-than-air purposes, and the Airship Service can hardly be debited with any trouble which ensued, in fact the personnel deserves great credit for the performance they have put up with the indifferent material at their disposal. The production of efficient airship engines only requires official encouragement in the shape of orders. The engine illustrated on the last slide is probably the only engine designed essentially for airship purposes. This engine includes in the specification most of the points the Author had specially called for in his paper. The design of this engine has been based on reliability, economy and accessibility. From the reliability point of view it is interesting to note that the test of this engine includes a 100 hour non-stop run at full throttle at the normal speed. The comparatively low normal speed of the engine, of 1,400 r.p.m., is a considerable factor where extreme economy is required. As regards accessibility, it is sufficient to remark that a cylinder can be removed without dismantling anything else, and that once the cylinder is removed, a piston or connecting rod can be changed without any further dismantling.

For instance, a few days ago, during the trial of this engine, a cylinder was removed, a piston changed, the cylinder replaced and the engine running again in 65 minutes, which, it must be admitted, is rather good.

Regarding airship machinery, under present conditions it is necessary to fit gear boxes, but it is probable that in the near future these can be dispensed with, when efficient low speed airship engines have been developed. It is the difficulty in installing and connecting the gear boxes and propellers to the engines which complicated the present airship installations, as it was necessary that all connections should be very flexible and yet should be capable of transmitting high torque. It is suggested that the well-known principle of three-point suspension should be applied to airship gondolas. The suspensory girders for engines and machinery would form the chief part of the gondola, and would be suspended on three points so that they would remain in approximately correct alignment, no matter what stress was met with. The outer casing of the gondola and the gangways could be made separate from the suspensory girders and not integral as at present, and should be suspended on the same suspension points as the engine girders. If this could be done, any alteration in the disposal of weights in the gondola would not affect the alignment of machinery. This method of suspension would also lend itself to Commander Cave-Browne-Cave's suggestion that the complete power units should be completely detachable. From the point of view of accessibility and space occupied, it is thought that engines with the cylinders in line are the best, particularly as the question of engine weight is not so important as in aeroplane work. Engines are already in use with eight and twelve cylinders in line, for other purposes, and no doubt this design of engine could be developed for airship work if thought fit.

Referring to the Lecturer's remarks on the overheating of the air-cooled engines used with the B.E.2C. fuselage slung on the first S.S. airship, it would perhaps be interesting to give the results of some experiments carried out with the measuring of air speed immediately behind the propeller on this particular type of installation. It was found that at any radius less than 15in. from the centre of the air screw, the air velocity behind the propeller is less than the actual forward speed of the airship. At a 12in. radius, the air speed is only 80 per cent. of the forward speed. From this it will be seen that the cooling effect of the slip-

stream is negligible within a 30in. diameter circle, within which circle the hottest parts of the engine are situated, and to get any advantage from the slipstream to aid in the cooling, it is necessary to have very high cowls.

Major Abell's suggestion that the power plant should be centralised and propellers situated in positions along the airship where the maximum efficiency could be obtained, is ideal, but it is not possible to efficiently carry out this idea with any method of driving through shaft lines. However, as the development of hydraulic transmission is now receiving considerable thought and is particularly applicable to this requirement, it is probable that eventually the "central power house" will be obtainable.

Major B. C. CARTER said the point from which one started was the number of hours flight. One hundred hours seemed to be a great deal to arrange for, and the airship was being used for carrying fuel. For commercial purposes he thought it would be better to interrupt overland journeys and take on more fuel, unless the expense of having a number of men on the ground to attend to that work would counterbalance the advantage. He had been looking into the question of using a heavier fuel than petrol, particularly for aeroplane engines. For heavier-than-air machines the engine should not weigh more than about 3lbs. per h.p. The trouble was that when one went over to the constant pressure cycle it was difficult to get the combustion to take place at a sufficient speed. One must work with fairly high piston speed and yet one was limited in the number of r.p.m., because the time available for the fuel to mix and burn was so short at high revolutions. That brought one to a longer stroke to keep the piston speed up, and there must be a large bore cylinder to keep the weight-power ratio reasonable. Then one came to a big cylinder, and to get a fairly even torque, one could not have *less* than six cylinders, and the result was a high-power engine. Air cooling might be used to save weight. He would like to have Major Abell's views on that matter. Recent experiments at the R.A.E. showed that good consumptions could be obtained. With a small air-cooled cylinder, a consumption of .48lbs. per b.h.p. hour had been obtained; and with a larger cylinder, .5lbs. per b.h.p. hour. These were good figures and would be reasonable for airships. It was a question whether the installation could be arranged to make an air-cooled engine accessible while ensuring that it gets the necessary cooling draft under all conditions that apply.

Major G. H. ABELL said the lecturer suggested large inspection doors on the engine crankcase, and that the camshafts should be in the base chamber of the engine. The two are incompatible. One could have the inspection doors, but the camshafts would be an obstruction in the way of getting at the connecting rods. He favoured having the camshaft overhead. He did not think that the point regarding the upsetting of the timing if the camshaft had to be removed in the air, was a serious one. One could have master serrations on the shafts or the gear wheels could be plainly marked.

With regard to the large cylinders that were suggested. If pre-ignition occurred it would be a serious matter. He was strongly in favour of the abolition of the gearbox, but unless this could be done there would be a liability of damage to the gears or universal joints due to reversal of stress caused by pre-ignition in one cylinder, unless the factor of safety, and consequently the weight, were very high. He believed it would eventually be possible to use air-cooled engines in airships. Experimental work regarding air-cooled cylinders for aeroplanes was very encouraging. These experiments showed that it was quite possible to run air-cooled cylinders with as high a mean effective pressure as in water-cooled cylinders, with the result that the petrol consumption was equally good. An enormous amount of complication would be saved by this means, including the liability of damage due to frost at high altitudes.

Captain A. C. BURGOYNE said the question was whether it was better to design an engine with which one could make adjustments and repairs in the air, or design an engine that did not contain the parts that gave trouble. The two-stroke hot bulb engine used with direct injection of a heavy fuel-paraffin or something heavier, might be made fairly light. Maudslay's engines were made some years ago with the large inspection doors. It was not possible to design engines with two camshafts in the crank case, and then get the pistons and connecting rods out. The Author said a desirable lay-out was to have a large engine or engines in the gondola with the propellers 50ft. away. With swivelling propellers and shaft drives that did not appeal to him. He thought there were possibilities in electrical transmission. The engines might drive high-speed alternators; a speed of 20,000 r.p.m. would not be impossible. The propellers would be driven by equally high-speed motors, and he did not think the double helical gearing would be very heavy. It should be reliable, as the transmission would be by flexible cables. Electric starters for engines had been used and worked satisfactorily, but they were heavy because they involved batteries. A 500 h.p. engine could be started with 70lb. of battery, starting gear, and motor. He suggested putting in a central electric power plant in the airship, an engine of 5 to 10 h.p. driving a dynamo wound for shunt and compound running. In the ordinary way that engine could be kept running for doing auxiliary work and working pumps, wireless, etc. For starting, the compound winding would be put in, and each engine would be started direct from the central power station. A light battery would have to be carried for running the wireless which could not be run direct off the generators. Why not take the engine out through the bottom of the gondola? It might obviate taking the gondola off the airship.

Mr. A. E. PARNACOTT said, with regard to the proposal to have a large number of cylinders in a line, there were basic principles underlying the design of all structures. The crank shaft and the crank chamber could each be looked upon as a beam. There was an action from the crank shaft and a reaction from the crank chamber. The weight of those structures for a given strength increased as the cube of the lineal dimensions. Consequently a long crankshaft for a given strength had to be much heavier, as did also the crank chamber for a given power. He thought the air service was wrong in going for that in-line type of engine. There were troubles with connecting rods, water joints, pistons, etc., and these were largely due to the springing of the crankshaft in one direction and the crank chamber in the other. Engines should be made as rigid as possible. The rigidity fell off more rapidly than the strength for the length. Special attention should be given to an engine where the reciprocating parts were locally balanced, as could be the case with the two-throw crank shaft and the opposed type of cylinder. One would thus get a lighter engine and one less liable to breaks, which were largely due to the flexibility of the crank shaft and crank chamber.

General HIGGINS said he had no remarks to make except to express his appreciation of the Lecture.

In reply to the discussion, the Author did not think the basis of 100 hours flight was excessive. Owing to their limited speed, airships were at the present moment more liable than aeroplanes to meet weather conditions which would necessitate their remaining in the air for indefinite periods, and he thought that the flight of the R.34 to New York was an instance of this.

With regard to air cooling, great strides had been made in the design of air-cooled cylinders with high brake mean pressures, figures of 130lbs. per sq. m. having been maintained, but there were difficulties in the way of the adoption of this type of engine in airships. There was, of course, the cooling question. It was difficult to cool a single line engine by means of air, and if radial engines were used, the cooling difficulties might be overcome, but on the other hand, the even distribution of mixture at all speeds, would present difficulties which were

very great, and at the present moment were, he thought, being made the subject of experiment.

With reference to the question of inspection doors, he did not agree that the fitting of camshafts in the base chamber ruled out altogether the possibility of providing inspection doors. Suitable design could arrange a layout including both features. He thought, however, that, given an easily detachable cylinder, a small inspection door sufficient only to get at the big-end bolts might meet the requirements.

Referring to the question of hot bulb engines advocated by Major Burgoyne, the Author did not think these could be built light enough, owing to the precautions which had to be taken to safeguard against possible pre-ignition and the effects resulting therefrom. With regard to the possibilities of electric transmission and speeds of 20,000 per minute suggested, this did not appeal to him, as it would involve high speed gearing both in the engine room and in the propeller boxes, which would be inaccessible, and in addition, the alternators would be too heavy.

The criticisms raised by Mr. Parnacott on the single line engine were no doubt true to a certain extent, but such engines had been built to run satisfactorily for long periods, and where failures had occurred, the Author thought the causes were due more to faults other than the fact that the crank shaft and crankcase were flexible.

Votes of thanks were accorded to the Lecturer on the motion of the Chairman, and to the Chairman on the motion of General Maitland, who bore testimony to the Chairman's brilliant technical abilities and his skill as a pilot. As controller of the technical department he bore extremely responsible duties on very young shoulders, and had done a great deal to develop aviation.

REVIEWS.

The Theory and Practice of Aeroplane Design, by St. G. Andrews and S. F. Benson. D.U. Technical Series. Chapman and Hall, 15/6 net.

The authors show courage in facing to-day's strenuous competition in meeting the long-recognised need (*en cliché* the long-felt want) of a reliable text book on their subject. They profess a logical and mathematical treatment in contrast with some contemporary authors who profess freedom from both, but the results are not much different. Whenever mathematical technique, or training in physics, or powers of logical expression, or practical experience is inadequate, exposition weakens and fails.

On the whole the authors have collected in one text book a considerable mass of fairly well arranged information from, chiefly, A.C.A. publications. Their treatment is on fairly sound lines, but is not so reliable as one might wish.

On page 11 they take the drag component of the aerodynamic reaction as a *localised* vector whereas it is an unlocalised vector.

On page 35 they propose to suspend an inverted machine from the centre of gravity as if this were equivalent to reversing the gravitational forces distributed over the component parts of structure and load.

On page 304 it is stated that the resistance derivatives are independent of the aeroplane's motion, which is contradicted by merely writing them down Xu, Xv, Zw, etc. The use of drift for drag, factor of safety for load factor, absolute for non-dimensional, efficiency for other relations than output/input are to be avoided. ϵ usually denotes a small quantity, but here denotes efficiency in the correct sense. The statements: "It follows from this that the more efficient a machine is, the more it pays to make it efficient" (p. 209), and "Such a complexity of systems of loading leads to a symmetrical method of construction" (p. 241), are too transcendental.

On p. 107 the authors give as *m.* of *i.* of a tapered strut section in in.^{4} 28509652.1. We think the possible accuracy of measurement does not justify going beyond the decimal place.

The elaborate investigation of struts might well have been replaced by Mr. Webb's conclusions in graphical form.

In stability A, B, C, D, have three different sets of meanings, and the old-fashioned left-hand system and non-alphabetical ϕ, θ, ψ, for notations about oX oY oZ make the subject wearisome to follow.

Bairstow's "very able" 1912-13 work has, however, been fairly completely transcribed.

The mechanical production of the book is excellent.

To sum up the authors impress one as being earnest students rather than competent masters of their subject.

The Design of Screw Propellers, by Henry C. Watts, M.B.E. Longmans, Green and Co., 25s. net.

In the early days of aircraft engineering, a designer had to be an all-round man, capable of designing every part and detail of his machine, but, when the requirements of war demanded high pressure output on the design no less than on the construction side of the trade, some specialisation of design work became inevitable. This has gone so far that at the present time we find specialists in stress, performance, stability, propellers, boat hulls, and what not, with the result that it is difficult for anyone to keep properly abreast of all the ramifications of his subject.

Fortunately a few of the best specialists have been engaged since the war in writing text books on their own special branches, so that now it is possible for the old-fashioned aeronautical engineer, who wishes to be more than a specialist, to catch up some of the ground lost under force of war pressure.

One of the latest of these text books is "The Design of Screw Propellers for Aircraft," by H. C. Watts, who is well known as the propeller designer to the Air Department of the Admiralty and to the Air Board, while his mission to America will also be remembered.

It goes without saying that with his unique experience of propeller design, Mr. Watts has written a sound and comprehensive treatise, but he has done much more than merely this, for he has written a book which will be of real value to a man learning propeller design for the first time. A student so approaching the subject will find after suitable introductory chapters the simple Drzewiecki theory set out in a really clear manner, followed by a chapter which goes into the practical method of application of the theory.

The next section of the work, comprising Chapters VI. and VII., deals with the inflow theory, and its relation to the simple theory, and finishes with the latest refinement, the "combined" theory. This part of the book is of absorbing interest, as the author leads us easily through ways that are difficult to follow at the best, and have been made worse by rather hot-headed controversy in the past. His conclusions are clearly set down and clearly proved and we may hope that this branch of the subject will be far better understood in the future than it has been in the past.

The later chapters deal with the advanced portions of the theory of propeller design, such as the choice of angle of incidence, and with some side issues of great general interest, such as tandem propellers, variable pitch, the use of gearing, windmills and so on. There is also of course a complete discussion of the problem of propeller strength, with the methods to be used for practical computation.

One gathers from the preface that the author hopes to deal with helicopters in his next edition. This will be looked forward to with interest, but probably there will be a greater demand by that time for a sound discussion of metal propellers, and it is to be hoped that he will be able to find room for this subject. Some of us would also like to see the case for and against variable mechanical gearing analysed, much on the lines of the analysis of the variable pitch propeller, which is included in the present edition.

The propeller man will probably find the greatest value of the book to lie—apart from its clearness and reliability—in the fact that the author has explained fully the methods of computation to be used instead of leaving the reader to dig these out of the equations as best he can, and has, in every case, given his readers the benefit of his great experience by quoting the values of the correcting co-efficients which are such a necessary feature of practical propeller designing.

The general designer, on the other hand, will find more interest in the chapters which deal with such subjects as gearing, two-bladed versus four-bladed propellers, the necessary diameter to allow for the propeller when designing a machine, slip stream, body interference, and so on.

In a word, the book is the careful work of a master of the subject and seems destined to become a standard both for routine use and for occasional reference in difficulty.

HARRIS BOOTH.